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Infrastructure
Canada

UNCLASSIFIED

BRIEFING NOTE TO THE MINISTER OF INFRASTRUCTURE AND COMMUNITIES

THE CLIMATE LENS

(For Information)

PURPOSE

- This note provides an overview of Infrastructure Canada's Climate Lens: what it is, when it applies, provincial/territorial feedback, and how it has been used thus far.

HIGHLIGHTS/KEY CONSIDERATIONS

What is the Climate Lens?

- The Climate Lens is a project-level assessment developed in partnership with Environment and Climate Change Canada (ECCC). It was introduced in June 2018 aiming to change project planning and decision-making to factor-in climate mitigation and adaptation (resiliency) considerations. It is made up of two parts:
    - The *Greenhouse Gas (GHG) Mitigation Assessment* requires that projects assess their expected GHG emissions against a baseline; and
    - The *Climate Resilience Assessment* requires that projects plan for and manage the risks of the changing climate.

When does it apply?

- The Climate Lens applies to all projects over $10 million under the Investing in Canada Infrastructure Program (ICIP); to all Disaster Mitigation and Adaptation Fund projects; and to any winning Smart Cities Challenge projects with a climate focus.

- It also serves as an eligibility test for projects under the two climate change sub-streams of the $9.2 billion Green Infrastructure Stream of the Investing in Canada Infrastructure Program. Projects within the climate change mitigation- or adaptation-focused sub-streams must submit their Climate Lens assessments as part of project approval (**Annex A**).

- Outside these sub-streams, projects can defer the submission of their assessments to after project approval, but they must be submitted before first federal payment. Under certain conditions, an exemption from the requirement can be approved by the Minister of Infrastructure.

What has been the reaction from stakeholders?

- Initial feedback has highlighted the following:
    - Significant regional differences exist across the country in the capacity to complete the Lens, and small communities generally have less capacity;
    - [redacted]
    - Professional firms consulted see the Lens as workable and valuable; and [redacted]

How has it been used thus far?

- So far, 219 Climate Lens assessments have been triggered, with 39 exempt, 72 completed, and 108 deferred. The following breaks down project value covered by completed assessments to date:
    - 41 GHG mitigation assessments, of which 33 cover projects over $10M in eligible costs; and
    - 31 Resilience assessments, of which 25 cover projects over $10M in eligible costs.

- With the initial release of the Climate Lens General Guidance in June 2018, there was an approximate six-month period where there were some early exemptions so that construction would not be delayed on projects ready to start right away.

- Frequently, deferrals from this period were also requested to ensure data availability and increased quality of assessment. The pool of professionals completing the Climate Lens has since grown, and the use of the Lens is more commonplace – lessening the rate of deferral.

- Fewer green stream projects have been put forward by provinces relative to other ICIP funding streams to date, which may play into the low number of assessments.

- The quality of assessments received has varied widely. Two selected high quality assessments are attached: Comox Valley Water Treatment and Inuvik Wind (**Annexes B and C**).

- [redacted] errors or poor quality data have been addressed through

the use of follow up "Conditions on Payment" that stipulate projects can be approved, but will not receive payment until these errors are addressed.

- Through the Lens, Infrastructure Canada also collects data to inform policy development and track its progress toward the ICIP goal of a GHG reduction of 10MT in 2030.
  - [redacted]
  - A formal roll-up of standardized data from submitted climate lens assessments to assess progress towards INFC's 10MT reduction target is a work in progress.

- A planned review is underway to substantially update the Climate Lens guidance, consider how to increase the impact of the Lens, and identify options to build broader capacity for undertaking the project assessment work. Planned updates to Lens guidance will include the development of sector specific guidance in collaboration with ECCC for larger projects such as transit or green energy.

NEXT STEPS

- We will return with proposed measures to improve the Climate Lens as a tool, and its application by provinces, municipalities and the practitioner community.

Kelly Gillis Deputy Minister Infrastructure and Communities	Date

Attachments:

Annex A – Thresholds for Climate Lens Requirements
Annex B – Comox Valley Water Treatment Resilience Assessment
Annex C – Inuvik Wind GHG Assessment

ANNEX A: Climate Lens Applicability Chart

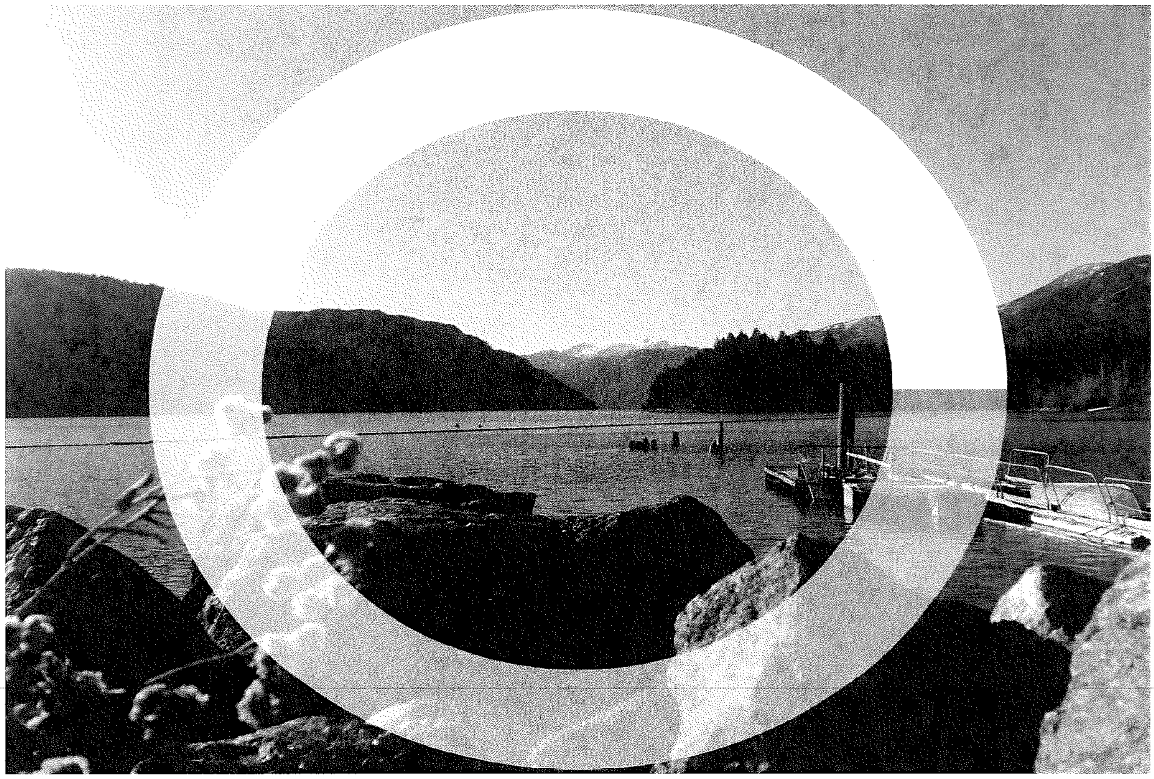
Programs and Streams	GHG Mitigation Assessment	Climate Change Resilience Assessment
Investing in Canada Infrastructure Program (*Integrated Bilateral Agreements*)		
Green Infrastructure – Climate Change Mitigation sub-stream	**All projects** (eligibility requirement)	If total eligible project costs are **$10M or greater**
Green Infrastructure – Adaptation, Resilience and Disaster Mitigation sub-stream	If total eligible project costs are **$10M or greater**	**All projects** (eligibility requirement)
Other streams and Sub-streams (Environmental Quality, Public Transit, Culture and Recreation, Rural and Northern Communities)	If total eligible project costs are **$10M or greater**	If total eligible project costs are **$10M or greater**
National Programs		
Disaster Mitigation and Adaptation Fund	**All projects**	The Climate Change Resilience Assessment is built into the DMAF application guide
Smart Cities Challenge (Winner)	If total eligible project costs are $10M or greater and project is a mitigation project	If total eligible project costs are $10M or greater and project is a climate change resilience project

COMOX VALLEY WATER TREATMENT PROJECT

CLIMATE LENS ASSESSMENT

PHASE 1 - CLIMATE CHANGE RESILIENCE ASSESSMENT

SEPTEMBER 12, 2018



CLIMATE LENS ASSESSMENT

PHASE 1 - CLIMATE CHANGE RESILIENCE ASSESSMENT

COMOX VALLEY WATER TREATMENT PROJECT

VERSION 3

PROJECT NO.: 17P-00108
DATE: SEPTEMBER 12, 2018

SIGNATURES

PREPARED BY

September 12, 2018

Date

September 12, 2018

Date

September 12, 2018

Date

APPROVED BY

September 12, 2018

Date

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1 ATTESTATION OF COMPLETENESS

We the undersigned attest that this Resilience Assessment was undertaken using recognized assessment tools and approaches (i.e. ISO 31000: 2009 Risk Management – Principles and Guidelines) and complies with the General Guidance and any relevant sector-specific technical guidance by Infrastructure Canada for use under the Climate Lens.

Prepared by: ______________________ Date: September 12, 2018

______________________ Date: September 12, 2018

______________________ Date: September 12, 2018

Validated by: ______________________ Date: September 12, 2018

2 EXECUTIVE SUMMARY

PROJECT OVERVIEW

commissioned by the Comox Valley Regional District (CVRD) to conduct a Climate Lens assessment for the Comox Valley Water Treatment Project (the Project). The Climate Lens consists of two elements: a GHG Mitigation Assessment and a Climate Change Resilience Assessment. This report provides the preliminary assessment phase (Phase 1) of the Climate Change Resilience Assessment. A separate report is available for the GHG Mitigation Assessment.

The Project consists of the construction of a new Comox Lake water intake, raw water pump station, filtration water treatment plant (WTP) with direct filtration and UV disinfection, and additional buried conveyance piping. New components will integrate with existing infrastructure including downstream conveyance piping, as well as emergency back-up pumping station and chlorination facility. The Project may also re-use two UV disinfection reactors currently housed in the chlorination facility, and will remove the existing water supply connection from a BC Hydro penstock.

The Project will provide safe drinking water for the region. CVRD commissioned the Project in response to a directive from the Vancouver Island Health Authority (Island Health) to provide filtration as part of their water treatment system. The Project will satisfy this Directive and bring CVRD into compliance with the British Columbia *Drinking Water Protection Act.*[1]

PHASE 1 ASSESSMENT METHODOLOGY

The Climate Change Resilience Assessment has been divided into two phases. This report, presenting Phase 1 of the assessment, consists of a climate sensitivity analysis and climate exposure analysis, culminating in an assessment of climate vulnerability for the Project. The outcome of Phase 1 determines whether Medium or High classification vulnerabilities are likely to present material risks to the Project and lays the groundwork for subsequent risk analysis in Phase 2.

The climate sensitivity analysis assessed the sensitivity of the project elements and project phases (i.e. construction, operation and maintenance) to 25 unique climate variables. The climate variables relevant to the Project included sea-related weather, precipitation, temperature, wind, evaporation, soil and pH.

The climate exposure analysis then evaluated current and future weather projections covering each climate sensitivity for the areas which could impact the Project. This analysis included specific focus on the areas encompassing the CVRD and the local watershed including Comox Lake, its tributaries and nearby glaciers.

[1] Government of British Columbia, Drinking Water Protection Act, Chapter 9 (SBC 2011).

CLIMATE VULNERABILITIES AND NEXT STEPS

The sensitivity and exposure assessments were combined to provide an overall assessment of vulnerability of the Project. The following Medium and High vulnerabilities were identified:

Construction:

- Extreme rainfall events (Medium)
- Extreme temperature events (Medium)
- Snow and ice (Medium)
- Gales and extreme wind events (Medium)
- Storms (snow, hail, dust and lightning) (Medium)

Operations and Maintenance:

- Glacier melt (High)
- Extreme temperature events (Medium)
- Change in average rainfall (Medium)
- Drought (Medium)
- Extreme rainfall events (flooding) (Medium)
- Changes in source lake water levels (Medium)
- Snow and ice (Medium)
- Gales and extreme wind events (Medium)
- Storms (snow, hail, dust and lightning) (Medium)
- Change in annual average evaporation (Medium)
- Soil stability (Medium)

Two High vulnerabilities and between five and nine Medium vulnerabilities were identified for each phase of the Project, covering sea-related weather, precipitation, temperature, wind and evaporation related variables. In all phases of the Project, soil and pH-related variables received a Low vulnerability rating, with the exception of soil stability during the operations and maintenance phase.

These vulnerabilities are expected to pose material risks such as flooding or damage to infrastructure during extreme weather events, and impacts to operations caused by changes to turbidity levels, water quality and water availability. Phase 2 of the assessment will provide a risk assessment to identify and evaluate climate- and weather-related risks to the Project, identify actions taken by the Project to reduce these risks and explore other adaptation actions to reduce climate risks to a manageable level prior to construction.

3 INTRODUCTION

3.1 BACKGROUND

3.1.1 CLIMATE LENS ASSESSMENT

was commissioned by the Comox Valley Regional District (CVRD) to conduct a Climate Lens assessment for the Comox Valley Water Treatment Project (the Project). The Climate Lens was created by Infrastructure Canada to help address climate change impacts and GHG emissions of infrastructure projects in Canada. By incorporating climate considerations during the planning and design of infrastructure projects, the Climate Lens is intended to help assess the impact of projects, influence the design process, and inform funding decisions. This effort is an essential part of federal and regional governments' strategy to achieving Canada's 2030 GHG reduction target of 30% below 2005 levels, as documented in the Pan-Canadian Framework for Clean Growth and Climate Change[2].

British Columbia and Vancouver Island face unique threats caused by climate change. These threats include an increased frequency of extreme weather events and chronic effects caused by incremental changes in temperature and weather conditions. Given the longevity of infrastructure projects and the role they play in supporting communities with critical services, it is important that these projects are built with the future in mind.

The Climate Lens consists of two elements: a GHG Mitigation Assessment and a Climate Change Resilience Assessment. This report provides the preliminary assessment phase (Phase 1) of the Climate Change Resilience Assessment.

3.1.2 PROJECT OVERVIEW

The Project is located near Courtenay, British Columbia and will draw water from Comox Lake. The Project consists of the construction of a new Comox Lake water intake, raw water pump station, filtration water treatment plant (WTP) with direct filtration and UV disinfection, and additional buried conveyance piping. New components will integrate with existing infrastructure including downstream conveyance piping, as well as emergency back-up pumping station and chlorination facility. The Project may also re-use two UV disinfection reactors currently housed in the chlorination facility, and will remove the existing water supply connection from a BC Hydro penstock.

CVRD commissioned the Project in response to a directive from the Vancouver Island Health Authority (Island Health) to provide filtration as part of their water treatment system. The region's existing water treatment consists of disinfection followed by chlorination treatment and does not provide filtration. In

[2] Environment and Climate Change Canada. (2016). *Pan-Canadian Framework on Clean Growth and Climate Change* (pp. 1-78, Rep.). Gatineau, Quebec: Environment and Climate Change Canada. doi:http://publications.gc.ca/site/eng/9.828774/publication.html

2014 and 2015, Boil Water Notices (BWN) were issued in response to increased turbidity levels lasting a total of 57 days, prompting VIHA to direct CVRD to provide a water treatment facility which included filtration before September 30, 2019. Complying with this directive would bring CVRD into compliance with the British Columbia *Drinking Water Protection Act.* Additional BWN events have occurred in 2016 and 2017.

3.2 APPROACH

The Climate Change Resilience Assessment has been divided into two phases. This report, presenting Phase 1 of the assessment, consists of a climate sensitivity analysis and climate exposure analysis, culminating in an assessment of climate vulnerability for the Project. The outcome of Phase 1 determines whether Medium or High classification vulnerabilities are likely to present material risks to the Project and lays the groundwork for subsequent risk analysis in Phase 2.

This phased approach allows the study to adjust the level of detail and focus of the risk analysis to the most relevant vulnerabilities and needs of the Project. This approach is consistent with the Climate Lens guidance, which suggests that a preliminary assessment phase may be appropriate to determine if more detailed analysis is required. Factors affecting the level of a Climate Lens Resilience Assessment include whether the asset is specifically intended to support resilience, if the asset is exposed to significant hazards, or if the Project likely faces Medium or High risks associated with climate change.

3.2.1 PHASE 1: PRELIMINARY RESILIENCE ASSESSMENT

The purpose of the Phase 1 assessment is to identify climate- and weather-related risks that the Project is likely to be vulnerable to. The steps undertaken in the assessment are illustrated in Figure 3-1 and described below.

Figure 3-1 Steps illustrating the preliminary resilience assessment process

The climate vulnerability assessment is informed by a climate sensitivity analysis and an assessment of climate exposure (both current and future). The sensitivity analysis focuses on identifying the sensitivities of the type of activities associated with the Project to extreme weather and climate change. As the focus is on the risks associated with weather and climate change, seismic activity and other environmental risks not caused by climate change have been excluded from this assessment. The sensitivity of the project elements has been determined in relation to a range of climate variables and climate-related hazards. A sensitivity rating and exposure rating table are used to summarize the main sensitivities and exposure of the proposed project elements to climate- and weather-related risks (see Appendix A-1).

The level of exposure of the project was determined based on historical weather data (where available) and an analysis of scenarios for projected future climate and literature review of climate hazards, taking into consideration the associated uncertainty. The vulnerability of project elements to climate- and

weather-related impacts is then determined by using a simple matrix (see Appendix A-1). High and Medium vulnerabilities are then taken forward to the detailed assessment stage (Phase 2).

3.2.2 PHASE 2: DETAILED RESILIENCE ASSESSMENT

The purpose of the Phase 2 assessment, to be completed following this report, is to identify risks and opportunities associated with the identified climate- and weather-related risks and to develop adaptation measures (costed where appropriate) that may reduce these risks. Details about the steps to be undertaken are described below.

The detailed resilience assessment is informed by:

- **Risk analysis** - in this stage, risks are identified and assessed in terms of the likelihood and consequence of each risk occurring and existing control measures are also identified. The effect of these control measures on residual risk is also described;
- **Risk evaluation** – in this stage, the risks are compared and ranked. The risks are evaluated to determine their severity, with special attention given to unacceptable risks with limited or no control measures in place. Possible adaptation measures are identified; and
- **Risk mitigation** – in this stage, an assessment is made of the feasibility, effectiveness and cost-benefits of each control or adaptation measure considered for unacceptable risks. These are compared with the status quo and return on investment calculated, where possible. The remaining (residual) risk is also described.

Undertaking the above steps is likely to involve engagement with the design team and key Project stakeholders (see Section 4.3).

The deliverable of Phase 2 will be a Climate Change Resilience Report that builds on the Phase 1 assessment and that meet the requirements of the Climate Lens. The outcome of the process will demonstrate that the climate risks to the Project have been identified and mitigated to a manageable level prior to construction.

3.2.3 PROJECT DOCUMENTS

The following Project information was consulted in undertaking the assessment:

- Comox Valley Water Treatment Project Description
    - Project location, overview, regulatory context
    - Potential project effects (health, socio-economic, heritage, environmental)
    - Indigenous group engagement details
    - Public consultation details
    - Project elements
- Comox Valley Water Treatment Plant Indicative Design Report
    - Project requirements
    - Permit details

    - Design criteria and details for each element (e.g. intake pipe) and discipline (e.g. structural, mechanical, etc.)
    - Commissioning requirements
    - Site security
    - Project construction costs
    - Technical appendices
- D-13124.00 Comox Valley Water Treatment Plant Risk Register
    - Risk descriptions
    - Mitigation actions/strategies

4 PROJECT DESCRIPTION

4.1 PROJECT ELEMENTS AND ASSET LIFETIME

The Project comprises the construction of:

- A filtration WTP
- A new water intake on Comox Lake and 0.5 km of submerged pipeline
- A Raw Water Pump Station (RWPS); and
- Buried conveyance piping (5 km treated water conveyance and 2.5 km of raw water conveyance)

The maximum daily capacity of the WTP is 75 ML/day, ultimately expandable to 120 ML/day if necessary to respond to future demand.

For the purposes of this assessment, these assets are herein described as WTP and supporting infrastructure. To identify the bounding timeframe over which this assessment has been undertaken it is necessary to consider the design lifetimes of the project elements, these are detailed in Table 4-1.

Table 4-1 Asset lifetimes

Asset	Expected lifetime (civil components)
Structures (including WTP and Raw Water Pump Station)	100 years
Mechanical Components	10-20 years
Operations	30 years

Whenever possible, climate conditions have been projected to the expected lifetime of the Project. However, there are limitations in the capabilities and availability of climate models which often only forecast to the end of this century. As such, this assessment is confined to those boundaries.

4.2 STUDY AREA

The study area aims to include the project site as well as nearby elements which may impact the construction, operation and maintenance of the project. The Project is located in the CVRD near the City of Courtenay, situated on the central east coast of Vancouver Island, British Columbia. The project is bordered by Comox Lake to the west and the City of Courtenay to the east. West of both the Project area and Comox Lake is the Comox glacier which acts as a source of freshwater for the Lake and by extension the Project. With these considerations in mind, the study area was deemed to be the entire Puntledge Watershed (Figure 4-1) inclusive of the Comox Glacier, with an emphasis on Comox Lake, and the proposed location of the WTP.

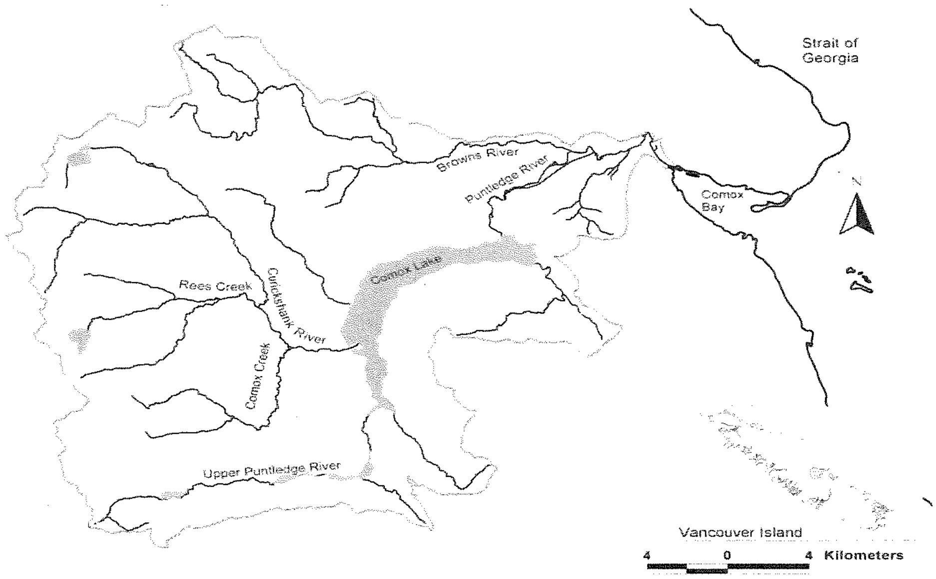

Figure 4-1 Puntledge River watershed boundary and major tributaries. Image courtesy of the Fish and Wildlife Compensation Program (2014).

The spatial boundaries of this assessment include the location of the Comox water intake, raw water pumping station, WTP, and end treated water main and is limited by the catchment boundary within which the proposed project is located (Figure 4-2).

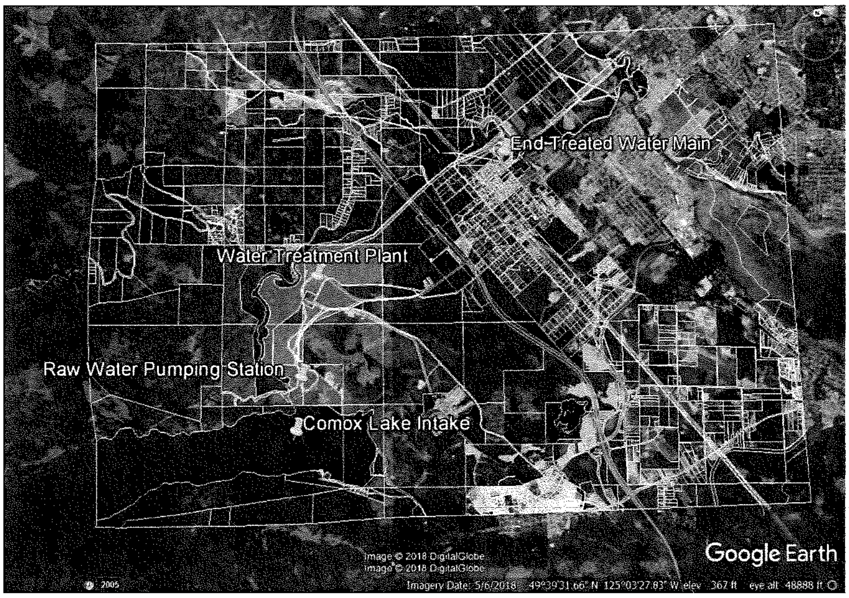

Figure 4-2 Location of elements included in the spatial boundary including Comox Lake intake, raw water pumping station, WTP and treated water main. Image courtesy of Google Earth with data points from the Comox Valley Water Treatment Project Description.

It should be noted that due to varying (spatial) scales and resolutions of historic data and climate change projection data, exposure may consider elements outside of the spatial scope of this assessment.

4.3 STAKEHOLDERS

Consultation with Project stakeholders was undertaken throughout the project development process, including:

- Public community groups and key stakeholders were engaged during the 2016 Project Definition Study;
- Specific correspondence between Indigenous Peoples and CVRD staff both during the Project Definition Study and thereafter; and
- Focused dialogue with specific land owners (related to Rights of Way and property acquisition) and with specific provincial offices (related to water licenses) were initiated in 2016 and remain active at the time of writing.

Table 4-2 includes a non-exhaustive list of stakeholders identified for this project.

Table 4-2 List of Project Stakeholders

Category	Stakeholder
Government	BC Environmental Assessment Office (BCEAO)
	Ministry of Forests, Lands and Natural Resource Operations (MFLNRO)
	Ministry of Transport and Infrastructure (MOTI)
	Vancouver Island Health Authority (Island Health)
	Transport Canada
	BC Parks
	Fisheries and Oceans Canada
	Department of National Defense
	Fortis
Utility	BC Hydro
	Hancock Forest Management
Forestry	Island Timberlands Ltd. Partnership
	Timberwest
	Comox Valley Conservation Strategy
NGO/Community Groups/Other	Community Partnership
	Comox Valley Land Trust
	Cumberland Lake Park Campground
	Comox Lake Land Corporation
	Morrison Creek Conservation

Category	Stakeholder
	Courtenay and District Fish and Game Protective Association
	Interested members of the general public
	Land owners and property managers within the Project area
	K'ómoks First Nation
Indigenous Groups	Qualicum First Nations
	We Wai Kai
	Tla'amin
	Wei Wai Kum First Nations
	Homalco (Xwemalhkwu) Indian Band

5 PHASE 1: PRELIMINARY RESILIENCE ASSESSMENT

5.1 OVERVIEW

This section describes the preliminary climate resilience assessment. The sensitivity of the water infrastructure sector to climate change is first considered before the exposure of the study area to climate change is outlined, focusing on Comox Valley, where possible. Key vulnerabilities are then identified before Medium and High vulnerabilities are recommended for detailed assessment in Phase 2.

5.2 VULNERABILITY ASSESSMENT

5.2.1 SENSITIVITY ANALYSIS

Using relevant guidance, Table 5-1 summarizes the climate variables and climate-related hazards for WTPs and supporting infrastructure. The identification of hazards has been adapted from the IISD Report on Climate Change Adaptation and Canadian Infrastructure (2013) and Standards Australia (2013); the latter represents a useful guide for assessing climate risks within the water and wastewater sector and so it has been adopted here. The resulting table indicates where the climate variable or climate-related hazard(s) are not relevant to the proposed Project. These climate variables and climate-related hazards have been omitted from the analysis.

The variables that remain are subsequently used throughout this report in the assessment of sensitivity (this section), exposure (Section 5.2.2) and vulnerability (Section 5.2.3).

Table 5-1 Climate variables and climate-related hazards: WTP and supporting infrastructure

Climate Variable	**Sensitivity Theme**	**Project Elements**
		WTP and Supporting Infrastructure
Sea	Sea level rise	Relevant
	Storm surge and storm tide	Relevant
	Surface temperature	Not Relevant
	Currents and waves	Not Relevant
Precipitation	Change in annual average rainfall	Relevant
	Drought	Relevant
	Extreme rainfall events (flooding)	Relevant
	Lake water level	Relevant

Climate Variable	Sensitivity Theme	Project Elements
		WTP and Supporting Infrastructure
Temperature	Changes in annual average temperature	Relevant
	Extreme temperature events	Relevant
	Glaciers	Relevant
	Solar radiation	Relevant
	Snow and ice	Relevant
Wind	Gales and extreme wind events	Relevant
	Storms (snow, hail, dust and lightning)	Relevant
	Cyclones	Not Relevant
Evaporation	Annual average humidity	Not Relevant
	Evaporation	Relevant
Soil	Moisture	Relevant
	Salinity/pH	Relevant
	Runoff	Relevant
	Stability	Relevant
pH	Soil	Relevant
	Fresh water	Relevant
	Marine and estuarine	Not Relevant

SEA

WTPs are sensitive to rising sea levels which can lead to saltwater intrusion into coastal aquifers and the upstream movement of saline water into estuaries, resulting in substantially higher treatment costs during operation.

Storm surge and storm tides may also lead to flooding of treatment works and loss of power, disruption of service and damage to infrastructure such as intake facilities, SCADA and telemetry equipment (Arkell *et al.,* 2012; EPA, 2015) during operation.

PRECIPITATION

WTPs are sensitive to changes in precipitation, principally changes in volume (also affecting turbidity) and flow (be it high or low) that affect water quality and operation. Climate change is likely to reduce the predictability of water availability (including snow melt which is relied upon as a source of surface water inflow into Comox Lake) and increase the likelihood of increased treatment being required. For example, concentrations of harmful chemicals and/or metals (such as nickel and phosphorus) may build up in waterbodies experiencing reduced inputs. To some extent, this may be countered by increased decay rates resulting from higher river water temperatures; the overall balance between these influences being determined by the relative contribution of point and diffuse sources, and the decay rate and length of river over which the decay operates (Arkell *et al.*, 2012).

Reduced rainfall may also lead to a decrease in reservoir levels relied upon by WTP and supporting infrastructure for plant operation.

Droughts may have an impact on the operation of WTPs through increased evaporation and less water availability (which can have negative impacts on water quality) and the increased requirement for treatment.

Extreme rainfall events can increase the mobilization of surface pollutants (e.g. pesticides), metals (e.g. manganese and iron) and sediments (e.g. Dissolved Organic Compounds) into rivers leading to more costly treatment and/or pre-treatment; this effect can be exacerbated particularly if heavy rain comes after a period of dry weather (Arkell *et al.,* 2012). Extreme rainfall may also reduce the number of days where construction activity is able to take place.

TEMPERATURE

WTPs are sensitive to high temperatures, temperature extremes and changes in solar radiation (radiant energy emitted by the sun) during both construction, operation and maintenance. Water temperatures in rivers and lakes typically correlate positively with air temperatures. Following an Arrhenius relationship, the rate of many common chemical reactions at room temperature doubles for every 10°C increase in temperature (Arkell *et al.*, 2012). Consequently, an increase in water temperature will affect water quality as processes such as dissolution, solubilization, complexation, degradation and evaporation are increasingly favoured. Collectively, this may lead to a concentration increase of dissolved substances in water and to a concentration decrease of dissolved gases (*ibid*) which may lead to greater treatment costs.

Some other likely impacts due to changes in these variables may include (but are not limited to):

- Extended residence times in slower moving rivers and waterbodies due to lower rainfall events, coupled with higher temperatures and the availability of phosphates and nitrates lead to higher rates of algal growth. The dissolve oxygen content in rivers can also reduce with lower river flows causing release of other pollutants (e.g. phosphorous) from bottom sediments (Arkell *et al.*, 2012);
- Increased septicity causing damage to water networks and treatment works and increased treatment costs (*ibid*);
- Increased temperatures and phosphorous concentrations associated with climate change are expected to increase the risk of algal blooms in reservoirs. In particular, populations of cyanobacteria are known to be linked to long periods of warm calm weather reflecting their slow growth rates and biological adaptations to stable mixing conditions (Reynolds, 1990; Jeppesen *et al.*, 1997);
- Changes in temperature, including growing seasons, can affect nutrient concentrations and may also affect the growth rate of Macrophytes in lakes and reservoirs. Some groups, in particular, can cause taste and odour problems (e.g. Charophytes);
- Alien non-native macrophyte species may become more prevalent in response to increases in temperature (Arkell *et al.*, 2012);
- Reduced number of days where construction activity can take place;
- Impacts of soil stability through caking of sediments and/or reducing moisture content which can in turn affect water quality (*ibid*); and
- Impacts upon operational processes, such as water treatment and reduced working hours during extreme events (e.g. extreme temperatures) (Arkell *et al.*, 2012).

Conversely, the extra heat made available through warmer temperatures may improve some aspects of treatment (i.e. coagulation and settlement processes) and lead to increased removal efficiencies and reduced treatment costs (Arkell *et al.*, 2012).

Increased temperatures are also likely to lead to glacier retreat which may limit inflow of freshwater into Comox Lake.

WIND

Storms can carry windswept material (particularly dust/sand) that can clog infrastructure (i.e. pipes and drains) affecting asset operation, water treatment processes, increase maintenance requirements and disrupt road networks and inspection regimes. Prolonged gusts of wind also aid evaporation.

Storms and high wind events can cause wide-spread power outages and disruptions by damaging power generation and infrastructure directly (lightning striking a power line) or indirectly (high winds causing objects to fall onto power lines). Short- and long-term power outages may impact the construction, operations and maintenance of site infrastructure.

Storms can also mobilize sediments containing heavy metals and increase turbidity which has a direct impact on coagulant demand and has been shown to increase the costs and challenges of treating water to potable standards (Longfield and Macklin, 1999; Miller and Yates, 2006; Rosenzweig *et al.,* 2007).

Dust storms may also reduce soil compaction or, conversely, promote subsidence thereby affecting the development of site infrastructure, including foundations.

EVAPORATION

Changes in evaporation can lead to reductions in water quality due to increased salinity and material left behind (i.e. concentrated salts) following evaporation; these materials may also be costlier to treat at WTPs. WTPs can be sensitive to increased rates of evaporation. Increasing rates of evapotranspiration are likely to reduce water quality and necessitate more (costly) treatment and energy requirements.

An overall decrease in rainfall, coupled with increased evaporation, may increase the stress placed on reservoirs and cause greater drawdown during drought periods (Arkell *et al.*, 2012). This may result in increased pumping into the reservoirs and less flexibility in the timing of pumping in relation to chemical or pollutant peaks.

Poorer water quality may also be caused by decreases in the buffering capacity of water systems. This may occur as water levels recede which can also lead to increased concentrations of nutrients, changes to turbidity conditions, an increase in salinity and potential thermal stratification (depending on the ambient temperature) (Arkell *et al.*, 2012).

SOILS AND PH

Reduced river flows, groundwater levels and soil moisture can increase the relative concentration of sediments, nutrients and pollutant loadings which can increase the requirement for water treatment. High temperatures and reduced rainfall can also accelerate the salination of soils, where water containing salty

dust and sand or pesticides evaporates, leaving the salt behind on soils; this may also lead to higher levels of sediment being passed into water channels, leading to a shift in water treatment requirements.

Increased precipitation (leading to high flows and/or turbidity) may lead to increased acidification and leaching of additional metals from soils. This is likely to lead to changes in pH which may in turn impact the hardness and alkalinity levels which are required to prevent corrosion and/or scale formation on structures (*ibid*).

Supporting infrastructure, such as conveyance piping, is sensitive to soil moisture content and soil stability. Drought and/or dry periods can lead to shrinking and cracking of soil substrates which can affect buried pipes and foundations.

Projected sea level rise, combined with higher water demand from coastal communities due to increasing temperatures, can lead to salt water intrusion, both in coastal groundwater aquifers and in estuaries. This combination may reduce water quality and increase treatment costs at WTPs drawing from coastal aquifers or from surface intakes in tidal estuaries near the saltwater line.

CLIMATE SENSITIVITY RATING

Based on the information described above, literature review and expert opinion, Table 5-2 and Table 5-3 summarize the climate sensitivity of the project during the construction, operation and maintenance phases respectively. The sensitivity ratings are defined as:

- High sensitivity (red): Climate variable/hazard may have a significant impact;
- Medium sensitivity (orange): Climate variable/hazard may have a slight impact; and
- Low sensitivity (green): Climate variable/hazard has little effect.

Table 5-2 Climate Sensitivity Rating (Construction)

Climate Variable	Sensitivity Theme	Justification/Evidence	Sensitivity Rating
Sea	Change in sea level	Limited sensitivity during construction phase.	Low
	Storm surge and storm tide	Flooding of construction site, disruption to activity.	Medium
Precipitation	Change in average rainfall	Limited sensitivity during construction phase.	Low
	Drought	Limited sensitivity during construction phase.	Low
	Extreme rainfall events (flooding)	Flooding of site during construction, reduced construction activity.	Medium
	Changes in source lake water levels	Reduced inputs to Comox Lake (and lowering water levels) may require intake to be relocated.	Low
Temperature	Change in average temperature	Limited sensitivity during construction phase.	Low

Climate Variable	Sensitivity Theme	Justification/Evidence	Sensitivity Rating
	Extreme temperature events	Affecting days where construction activity can take place. Extreme temperatures affecting concrete mixes, and health and safety of workers.	Medium
	Glaciers	Limited sensitivity during construction phase.	Low
	Solar radiation	Limited sensitivity during construction phase.	Low
	Snow and ice	Snow and ice can limit construction activity and cause damage to assets, including roofs and overhead power lines.	Medium
Wind	Gales and extreme wind events	Health and safety risk to workers from windswept material; disruptions to construction activity; power outages; dust storms reducing soil compaction or promoting subsidence affecting site construction.	Medium
	Storms (snow, hail, dust and lightning)	Lightning strikes and damage to power networks.	Medium
Evaporation	Change in annual average	Limited sensitivity during construction phase.	Low
Soil	Moisture	Flooding or extreme rainfall events can increase soil moisture and cause destabilisation of earthworks and foundations (e.g. clay soils in London area).	Medium
	Salinity	Limited sensitivity during construction phase.	Low
	Runoff	Limited sensitivity during construction phase.	Low
	Stability	Flooding or extreme rainfall events can increase soil moisture and cause destabilisation of earthworks and foundations (e.g. clay soils in London area).	Medium
pH	Soil	Limited sensitivity during construction phase.	Low
	Fresh water	Limited sensitivity during construction phase.	Low

Table 5-3 Climate Sensitivity Rating (Operation & Maintenance)

Climate Variable	Sensitivity theme	Justification/Evidence	Sensitivity Rating
Sea	Change in sea level	Sea-level rise leading to saltwater intrusion into coastal aquifers and upstream movement into estuaries – leading to higher treatment costs.	Medium
	Storm surge and storm tide	Flooding of WTP, disruption to operation, increased salinity.	Medium
Precipitation	Change in average rainfall	Principally affected by changes in volume (also affecting turbidity) and flow (high or low), leading to increased treatment requirements (e.g. accumulation of metals/pollutants). Reduced rainfall may lead to a decrease in Comox Lake water levels.	Medium
	Drought	Leading to more evaporation and less water availability and reduced water quality, thereby requiring additional treatment.	High
	Extreme rainfall events (flooding)	Increased mobilisation of surface pollutants (e.g. pesticides), metals and sediments into rivers and lakes leading to more costly treatment.	High
	Changes in source lake water levels	Reduced inputs to Comox Lake (and lowering water levels) may affect plant operation or require intake to be relocated.	High
Temperature	Change in average temperature	Increased water temperatures will affect water quality (e.g. increased concentration of dissolved substances). Extended residence times in slower moving rivers due to increased temperature and reduced rainfall. Warmer conditions leading to increases in algal blooms and nitrate concentrations.	Medium
	Extreme temperature events	Extreme temperatures affecting concrete mixes, health and safety of workers, operational processes such as water treatment, increased septicity, scaling down of activities during extreme temperature events, increased fire risk and damage to electrical and mechanical systems.	High
	Glaciers	Increased temperature leading to glacial retreat and reduced inflows to Comox Lake.	High

Climate Variable	Sensitivity theme	Justification/Evidence	Sensitivity Rating
	Solar radiation	Alongside evaporation, solar radiation can accelerate the biological and chemical degradation of water quality by increasing solubility and concentration of contaminants in water courses and growth of algae, parasites and microbes.	Low
	Snow and ice	Increased temperature leading to glacial retreat and snow/ice melt. Ultimately leading to reduced inflows to Comox Lake.	Medium
Wind	Gales and extreme wind events	Increased sediment mobility can clog pipes and drains affecting asset operation and water treatment, and increase maintenance and disruption to local road networks. Winds causing power outages and disruptions to power network (e.g. high winds causing objects to fall on power lines). Increased turbidity of Comox Lake.	Medium
	Storms (snow, hail, dust and lightning)	Storms can mobilize sediments and lead to increased treatment costs; Increased lightning strikes	Medium
Evaporation	Change in annual average	Reduced water quality due to increased salinity and material left behind (concentrated salts) leading to more costly treatment. This can be exacerbated by dry-wet cycles.	Medium
Soil	Moisture	Flooding or extreme rainfall events can increase soil moisture and cause destabilisation of earthworks and foundations, including to conveyance pipes.	Medium
	Salinity	Increased sediments input into river from increased temperature and reduced rainfall leaving concentrated salts and sediments.	Medium
	Runoff	Limited sensitivity during operation and maintenance phases. Could be an issue if dry-wet cycles increase (although likelihood of drought is low).	Low
	Stability	Flooding or extreme rainfall events can increase soil moisture and cause destabilisation of earthworks and foundations.	Medium

Climate Variable	Sensitivity theme	Justification/Evidence	Sensitivity Rating
pH	Soil	Limited sensitivity during operation and maintenance phases.	Low
	Fresh water	Increased salinity of Comox Lake during extreme temperature events and/or drought.	Medium

5.2.2 CLIMATE EXPOSURE

This section considers the exposure of the study area to extreme weather and climate change. In the context of this assessment, exposure is the presence of people, livelihoods, environmental services, infrastructure, economic, social, or cultural assets in areas which could be aversely affected by extreme weather or climate change.

Understanding changes in exposure requires analysis of a range of climate projections over the course of the Project's intended lifespan (see Table 4-1). The analysis presented here draws strongly from the Pacific Climate Impact's Consortium (PCIP) downscaled models, provided through the Climate Atlas online interface, flood mapping provided by the Government of British Columbia and the Coupled Model Intercomparison Project Phase 5 (CMIP5). CMIP5 data was used to underpin the findings of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The analysis is also supplemented by literature review.

The PCIP downscaled data was derived from 12 CMIP5 global climate models: GCMs: ACCESS1.0, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6.0, GFDL-ESM2G, HadGEM2-CC, HadGEM2-LR, INM-CM4, MPI-ESM-LR, MRI-CGCM3, and MIROC5. It uses baseline data from 1976 to 2005 and provides climate projections for two future timeslices: 2021 to 2050 and 2050 to 2100. The resolution of this data is 100km x 100km grids across Canada.

Climate change projections are founded on four scenarios of future GHG concentrations known as Representative Concentration Pathways (RCPs). These RCPs provide a range of possible trajectories of how global land use and emissions of GHGs and air pollutants may change throughout the 21st Century. They are named according to their radiative forcing values (the change in net irradiance in the troposphere due to external drivers) in the year 2100: 2.6, 4.5, 6.0, and 8.5 Wm-2 (IPCC, 2014). Therefore, RCP2.6 represents the least carbon intensive pathway while RCP8.5 represents the most. While RCP2.6 represents the lowest carbon scenario, it corresponds to a level of decarbonization which exceeds most ambitious decarbonization scenarios. As a result, RCP4.5 and RCP8.5 were selected for this study to best represent exposure in both high carbon and low carbon futures. Wherever possible, climate conditions were projected to both mid-century and end of century timescales to best coincide with the life of the assets (see Table 4-1).

Climate models also use baseline data as a reference period from which to derive and compare future changes in climate. Typically, a 30-year period of historic data of the climate variable that is being projected, such as temperature or precipitation, is used as a means of comparison. The choice of

baseline years varies from study to study, and is largely dependent on the availability of data, data quality and the intended purpose of comparison. This variability can be seen throughout the section that follows as each unique data source sometimes uses a different baseline period.

Ideally, climate projection data would be available for years which exactly match the lifespan of the project assets. However, by using readily available data, the projection data does not always align with the Project assets' lifetimes (see Table 4-1). Whenever possible, this assessment adopts mid-century (2050) and end-of-century projections (2100) to match the intended lifespan of the project's assets.

This exposure assessment has considered projected changes in the relevant climate variables presented in Table 5-1. Historical baseline conditions and projected changes, when the data is available, are described in the sections that follow.

The conditions of the Comox glacier and Comox Lake were considered using information gleaned from the literature and local data, where available. At the time of writing, a Puntledge River Fish Habitat Assessment is underway. Once completed, this assessment should provide valuable new insight into the historical and forecasted conditions of Comox Lake and Puntledge River.

SEA

SEA LEVEL CHANGE

Figure 5-1 shows projected global mean sea level rise (GMSL) for RCP4.5 and RCP8.5. Under RCP4.5 projections suggest a global mean sea level rise (GMSL) of 0.32m to 0.63m for 2081-2100 with a mean projected increase of 0.47m. RCP8.5 projects a higher sea level rise, with a mean increase of 0.74m by 2100.

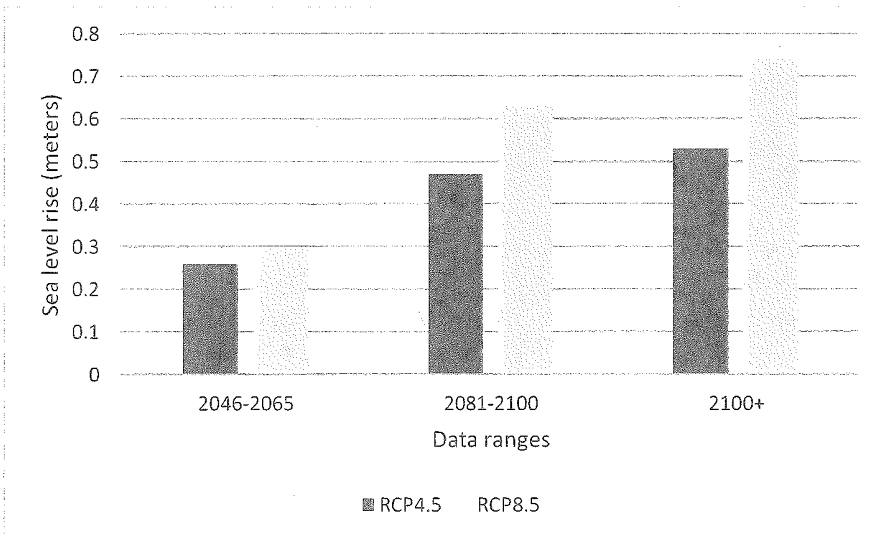

Figure 5-1 Comparison of the projected sea level rise under RCP4.5 and RCP8.5 for years 2046-2065, 2081-2100, and 2100. This data was acquired as mean level data points from the IPCC Fourth Assessment Report (IPCC, 2007).

STORM SURGE AND STORM TIDE

The project site is located approximately 140m above sea level and, as seen in Figure 5-2, is not located within a flood zone for a 200-year storm event. It is therefore unlikely that the site would be exposed to flooding from rising sea levels.

In addition, the elevation largely limits the amount of saltwater intrusion from coastal regions into local water supplies. Flood zone mapping was made available by the Government of British Columbia.

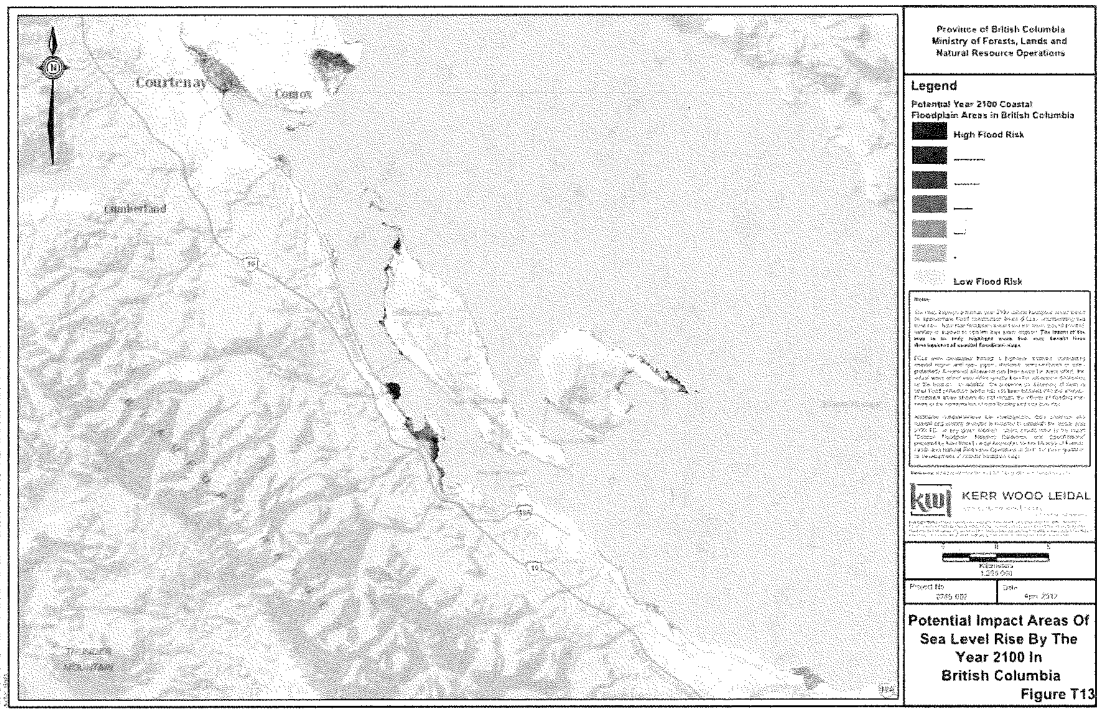

Figure 5-2 Flood map showing areas which would be impacted by a 200-year storm event in British Columbia. Image courtesy of the Government of British Columbia (2012).

PRECIPITATION

AVERAGE MONTHLY PRECIPITATION PROJECTIONS AND HISTORIC CONDITIONS

Figure 5-3 shows a comparison of the average seasonal historic baseline precipitation data from 1967 to 2005 with projected climate data for the years 2021-2050 and 2051-2080 under RCP8.5. This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above. The projections suggest an increase in seasonal precipitation in the spring, winter and fall and a decrease in the summer.

The most noticeable change occurs in the fall and winter, with a projected fall increase of 92mm from historic values to 2051-2080 and 83mm for winter in the same period.

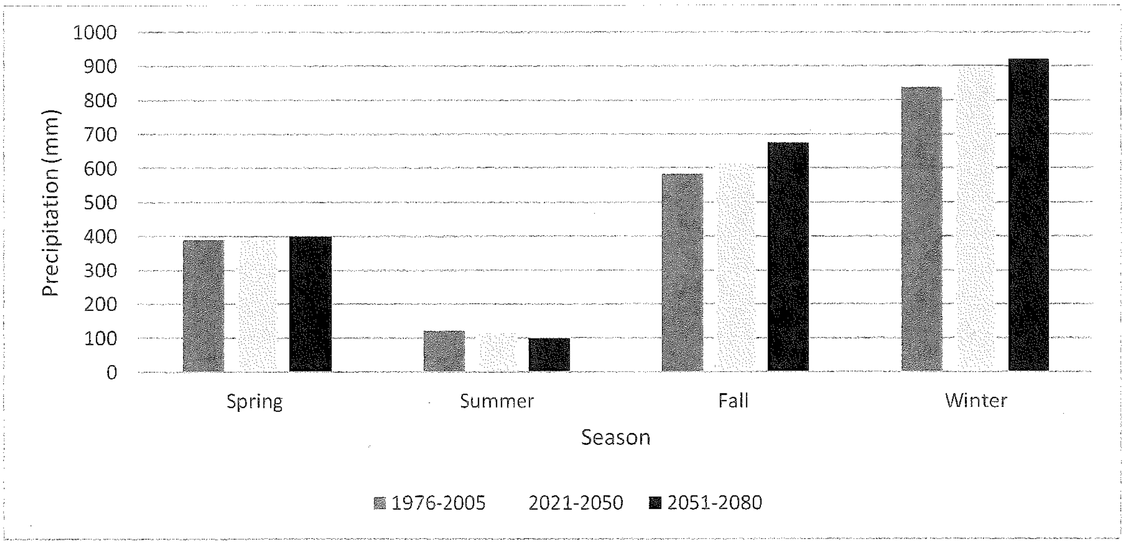

Figure 5-3 Average projected seasonal precipitation under RCP8.5 for the years 2021-2050 and 2051-2080 based on the PCIP downscaled models. This data was acquired as mean data points from Climate Atlas (2018).

Figure 5-4 illustrates the same climate output as Figure 5-3 under RCP4.5. The pattern of rising precipitation in the fall, winter and spring months, with a decrease in the summer seasons, is repeated with this data, though with considerably smaller changes. Under this scenario, winter is forecasted to experience the greatest changes with a projected increase of 76mm of precipitation between the historical baseline data and 2051-2080.

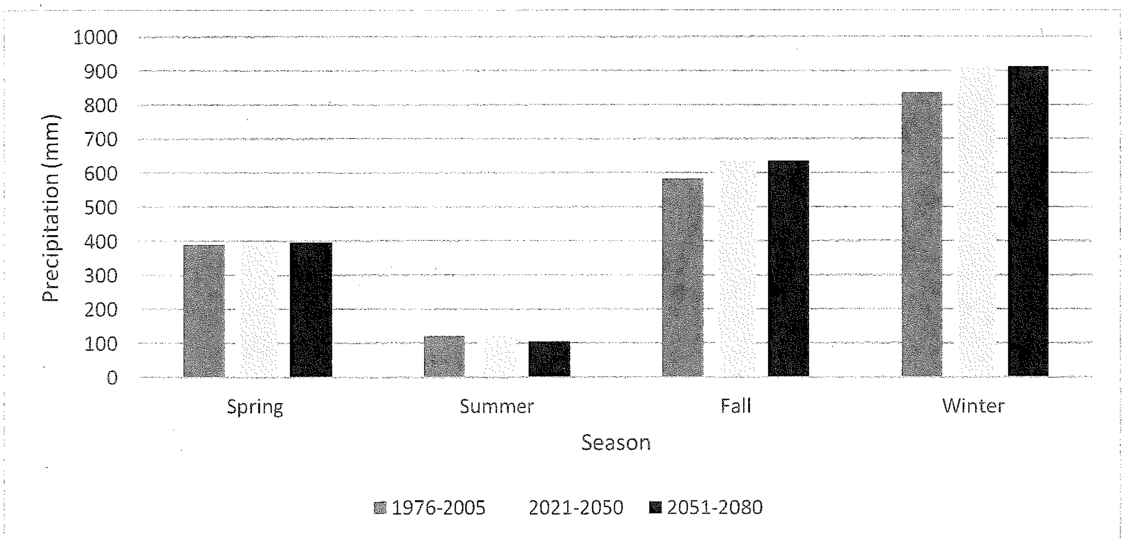

Figure 5-4 Average projected seasonal precipitation under RCP4.5 for the years 2021-2050 and 2051-2080 based on the PCIP downscaled models. This data was acquired as mean data points from Climate Atlas (2018).

DROUGHT CONDITIONS

In addition to considering precipitation, drought conditions can also be determined using a Climate Moisture Index (CMI). A CMI is the calculated difference between annual precipitation and potential evapotranspiration (PET) and is used to evaluate moisture conditions in a given area. Positive values indicate wet or moist conditions while negative values indicate dry conditions. The following data in Figure 5-5 was published by Natural Resources Canada and was created by downscaling monthly values of temperature and precipitation from the CanESM2 model (Canadian Earth System Model Version 2) under RCP8.5, and comparing them to calculated historical values using baseline years of 1981-2010. The data was projected to the years 2071-2100 for a 10km gridded area across the country. The data represented in Figure 5-5 is the projected 30-year average of that time range. RCP4.5 is not available for this model.

Comox Valley, and most of Vancouver Island itself, is projected to have a CMI Index of 40 or higher, which suggests an increase in moisture conditions in the region. This implies that there is little exposure of the area, and the Project, to drought conditions. A caveat is that it is derived on an annual timescale which therefore does not show seasonal variability. From the precipitation section of this report, Figure 5-3 and Figure 5-4 considered the seasonal variations in precipitation and in both RCP4.5 and RCP8.5 there were projected declines of precipitation in the summer months. This suggests that while annually drought is not projected for the region, there may be seasonal variability that should be considered.

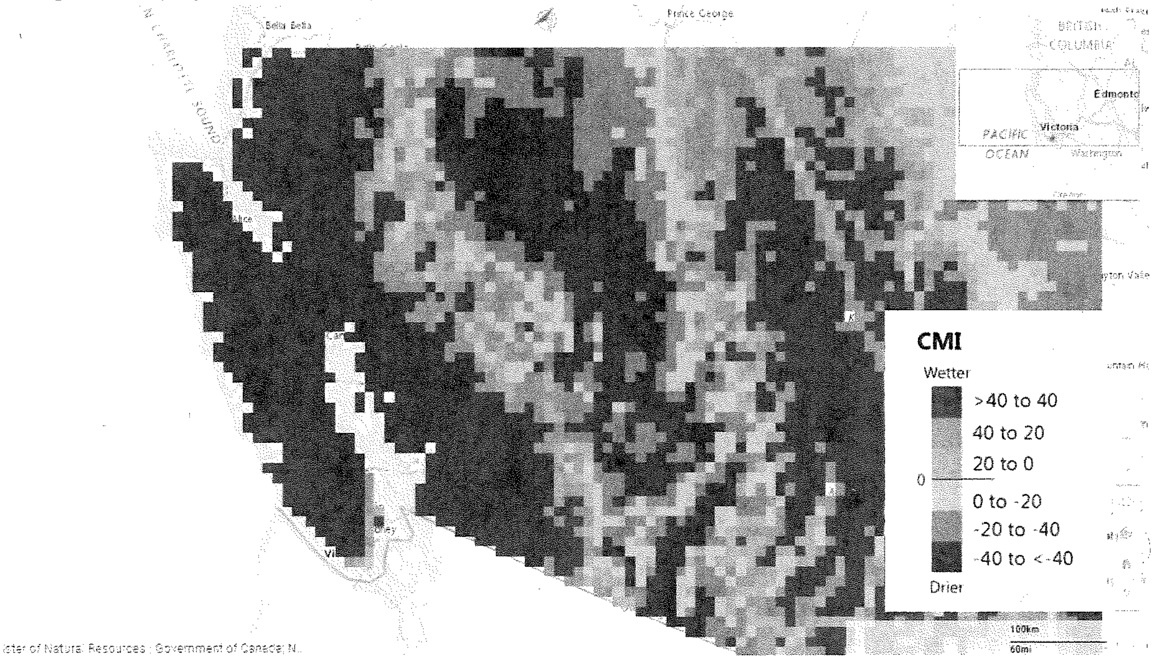

Figure 5-5 Climate Moisture Index projection for Comox Valley to the years 2071-2100 under RCP8.5 using a historic baseline of 1981-2010. Courtesy of Natural Resources Canada (2016).

AVERAGE ANNUAL HEAVY PRECIPITATION DAYS (20MM) PROJECTIONS AND HISTORIC CONDITIONS

Figure 5-6 shows the projected increase in mean heavy precipitation (precipitation over 20mm in one day) over the life of the project under RCP4.5 and RCP8.5. This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above.

RCP4.5 projects an initial average increase of 2.4 days of heavy precipitation per year for the years 2021-2050 compared to historical values. This is followed later in the century by a decrease of 0.1 days of heavy precipitation compared to the mid-century, which is still an increase of 2.3 days compared to historical levels. RCP8.5 projects a mid-century increase of 1.2 heavy precipitation days, less than the increase projected for RCP4.5. RCP8.5 then follows a continued upward trend towards the end of the century, with late century projections showing a mean increase of annual heavy precipitation days of 3.7 compared to the historical baseline. In either scenario there is an increase in the expected amount of heavy precipitation days, with the largest increase occurring between historical levels and the late century of the RCP8.5 with a jump from 28.1 heavy precipitation days to 31.1 (an increase of 3.7 days per year).

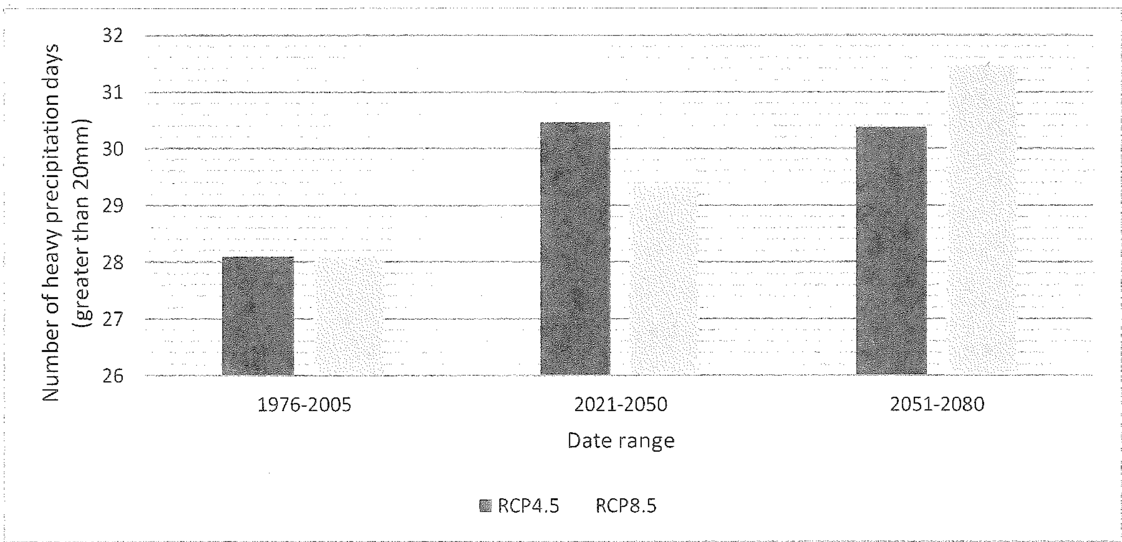

Figure 5-6 Average projected annual heavy precipitation days under RCP4.5 and RCP8.5 for 2021-2050 and 2051-2080 compared to a historical average (1976-2005) based on the PCIP downscaled models. This data was acquired as mean data points courtesy of Climate Atlas (2018).

HISTORIC FLOODING EVENTS

As part of a joint initiative between Environment and Climate Change Canada and the Government of British Columbia, a Floodplain Mapping Program was created between 1987 and 1998 to identify areas which were highly susceptible to flooding, defined by a 200-year flood (Ministry of Forests Lands and Natural Resources, 2018). This study identified Puntledge River and the nearby City of Courtenay as highly susceptible to flooding. The following is a list and description of some of the major flooding events which have occurred in the Comox and Puntledge water sheds on record:

- **February 1st, 1935,** A moderate flood occurred on Puntledge River, however newspaper accounts indicate that this was the largest flood in the preceding 40 to 60 years.
- **November 15th, 1939,** Heavy rain set a precipitation record of 83mm in 24 hours and combined with a high tide to create rapidly rising flood waters that newspapers described as more severe than the previously mentioned 1935 floods.
- **November 15th, 1953,** 229mm of rain fell in 5 days accompanied by high winds causing flooding.
- **November 13th, 1975,** Flood waters caused heavy inundation to Puntledge Park and Lewis Park.

- **December 26th, 1980,** Several days of warm temperatures and heavy rains resulted in heavy water discharge in the Puntledge basin and resulted in a record peak inflow to Comox Lake, though the floods were reported to not have been sustained for a long period of time. This event set a peak instantaneous flow for Puntledge river at the time.
- **February 11th, 1983,** Heavy precipitation of 80.2mm combined with warm temperatures and high winds caused flooding along the Tsolum, Courtenay, and Puntledge rivers.
- **November 12th-19th, 2009,** Heavy precipitation exceeding 100mm over the course of the weekend causing the Puntledge, Courtenay, Tsolum, and Brown rivers to swell over their banks. A state of emergency was declared for the nearby City of Courtenay. Peak flows of Puntledge river were recorded as $372m^3/s$ during this event.
- **January 14th-16th, 2010,** Heavy rains and warm weather caused the Puntledge and Tsolum Rivers to spill from their banks and cause flooding. The City of Courtenay experience localized flooding and a state of emergency was declared. Peak flows of Puntledge river were recorded as $525m^3/s$ during this event.
- **December 21st-29th , 2010,** A smaller flooding event occurred in the Puntledge, Courtenay, Tsolum, and Brown Rivers. Peak flow for the Puntledge river was recorded as $206m^3/s$ during this event.
- **December 10th , 2014,** In the beginning of December 2014 Comox Valley and the Alberni Valley received over 250mm of rain fell in a span of three days causing major flooding and leading to the mayor of nearby City of Courtenay to declare a state of emergency.
- **January 20th, 2018,** 148mm of precipitation fell in 24 hours resulting in swelling of the Puntledge and Cruikshank's rivers. The event caused the Comox Lake reservoir to rise to 134.93m, less than 1m from the dam's maximum capacity of 135.5m. A representative from BC Hydro noted that the Comox Dam was releasing 200m3/s of water, which is about six times the normal rate.

COMOX LAKE HISTORICAL WATER LEVELS

Historical water levels shown in Figure 5-7 were obtained from hydrological station 08HB082 'Comox Lake near Courtenay' and represent the mean maximum and minimum daily water levels of the lake from 1993 to 2017. Climate projections for this lake have not been conducted and are therefore not available to be used in this assessment. The Puntledge River Fish Habitat Assessment, once complete, should provide new information enabling a more thorough analysis of water levels in Comox Lake and Puntledge River.

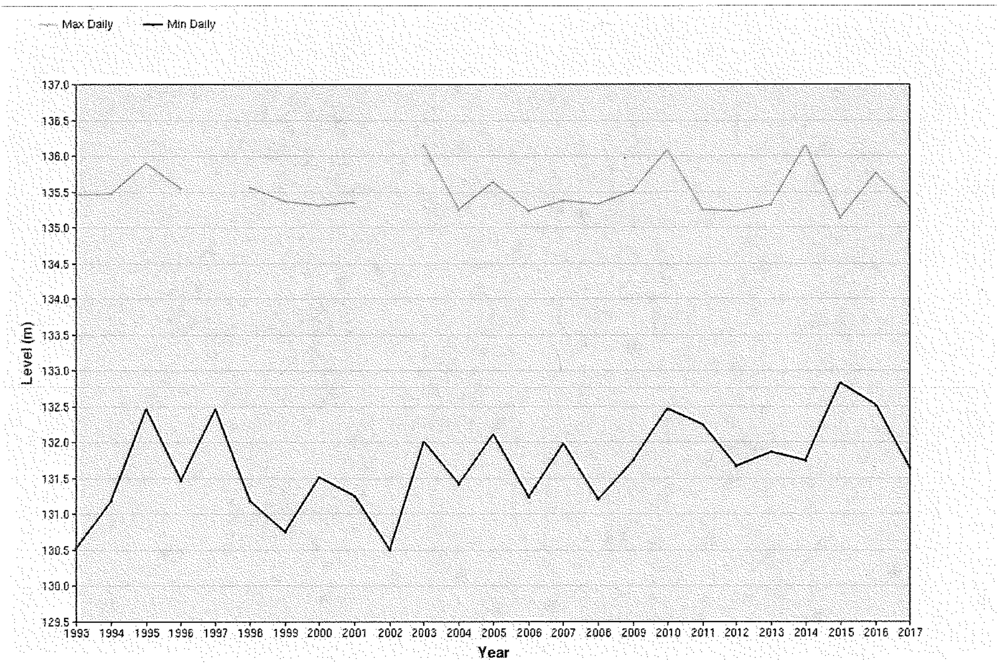

Figure 5-7 Comox Lake minimum and maximum annual water level data from 1993 to 2017. Data courtesy of Government of Canada (2018).

COMOX LAKE HISTORICAL TRIBUTARY DISCHARGE

Comox Lake was made into a reservoir in 1912 with the construction of a dam as part of the Puntledge Hydroelectric Project. The water level is control by BC Hydro in consultation with CVRD and BC Fisheries depending on the needs of the community, water levels of the lake, time of year, and fish mating. The dammed nature of the lake necessitates that water levels also be examined from a source of water that is not anthropogenically controlled. The Cruickshank river is a tributary to Comox Lake with available discharge information (Figure 5-8).

Figure 5-9 shows the average monthly trends in Comox Lake input from the Cruickshank River from 1982 to 2011 when the monitoring station was discontinued. January to February levels decrease as precipitation from winter snowfall decreases. When spring begins, the snowpack melt supplements the discharge and this peaks around the end of April. As drier summer months occur, the levels decrease until the beginning of fall, when temperatures decrease and precipitation increases. There is considerably more variability among the average maximum discharges compared to the minimum and even the mean. The levels from this tributary are affected by glacial snowpack, temperature, and precipitation, which are all projected to show changes due to climate change.

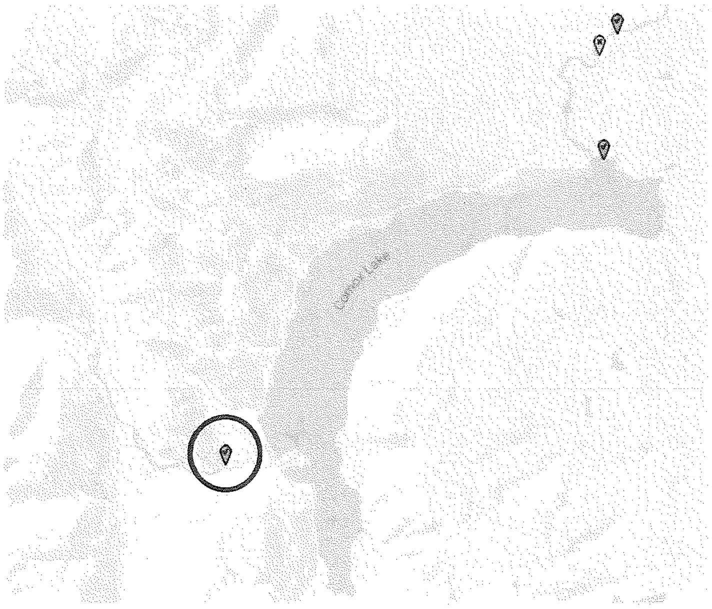

Figure 5-8 Location of the Cruickshanks River Discharge Monitoring Station (circled in red). Image courtesy of the Government of British Columbia Website.

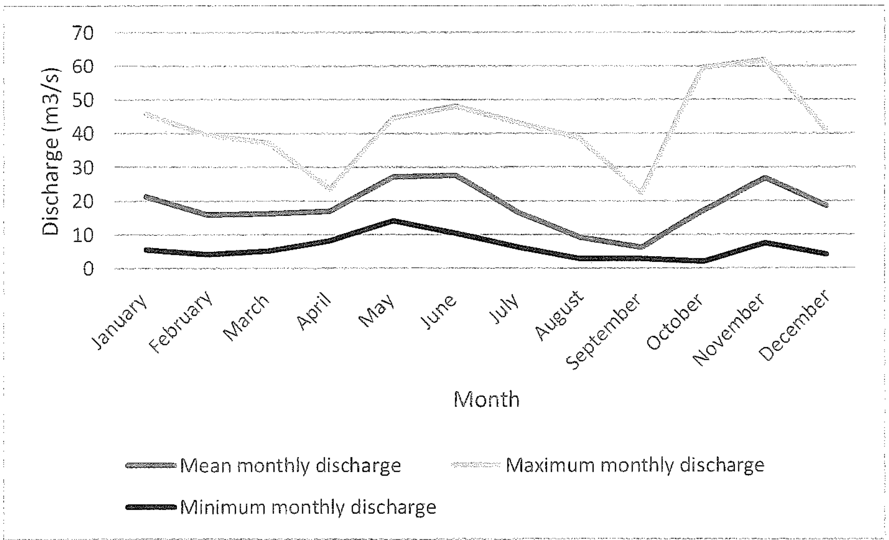

Figure 5-9 Mean, minimum, and maximum monthly flow discharge from the Cruickshanks River Monitoring Station averaged monthly form 1982-2011. Image and data courtesy of Environment Canada.

TEMPERATURE

AVERAGE SEASONAL TEMPERATURE PROJECTIONS AND HISTORIC CONDITIONS

Figure 5-10 and Figure 5-11 provide a comparison of historic data (1976-2005) with projected changes in seasonal temperatures for the years 2021-2050 and 2051-2080 under RCP8.5 and RCP4.5 respectively. Both scenarios predict increases in average temperatures for all seasons, with mean seasonal temperatures projected to reach as high as 20.4 °C in the summer under RCP8.5. Please note, daily maximum temperatures may exceed these values. This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above.

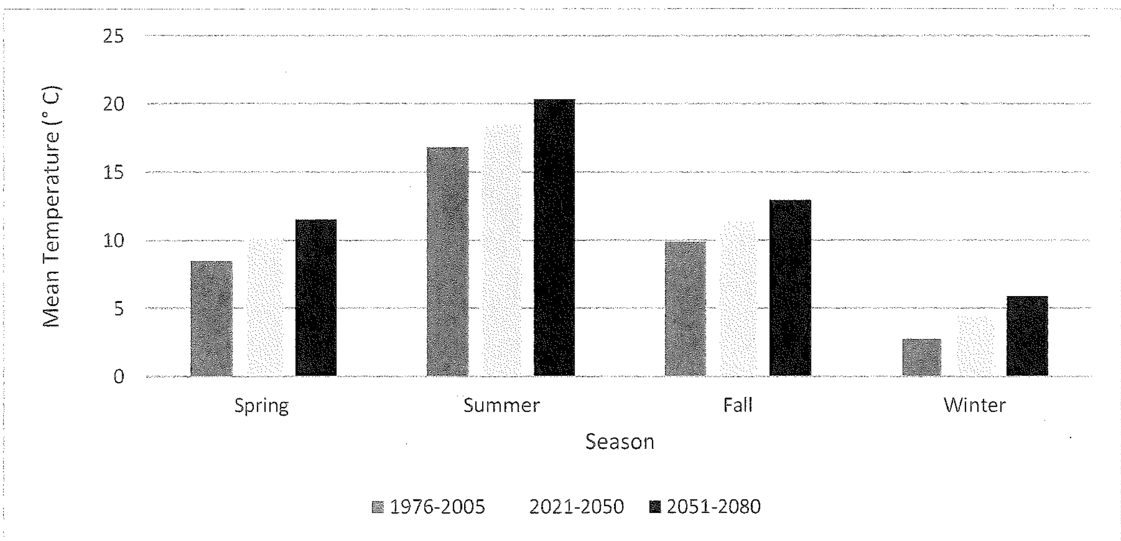

Figure 5-10 Average projected seasonal temperatures under RCP8.5 for 2021-2050 and 2051-2080 as compared to a historical baseline (1976-2005) based on the PCIP downscaled models. This data was acquired as mean data points courtesy of Climate Atlas (2018).

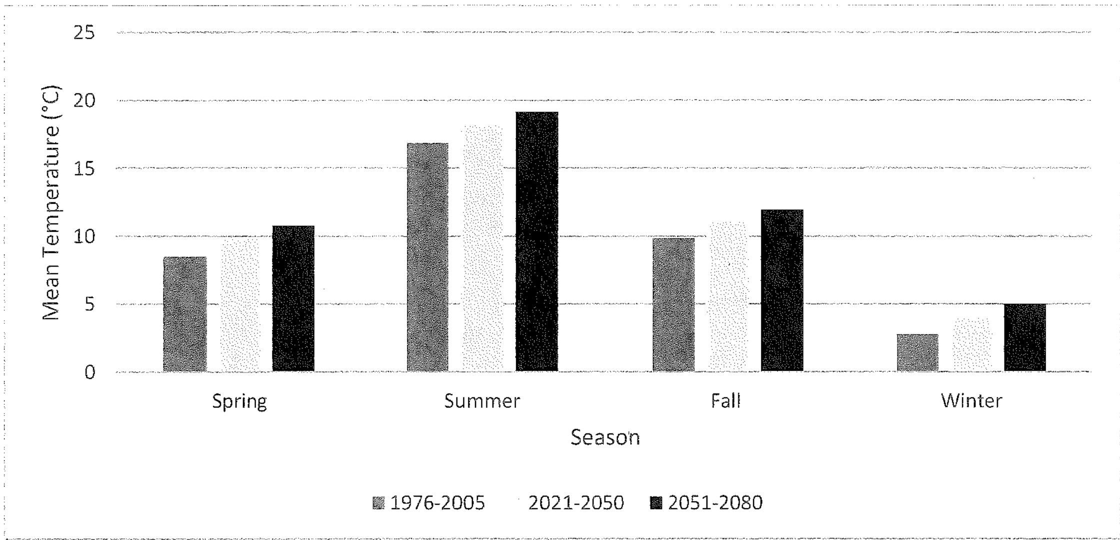

Figure 5-11 Average projected seasonal temperatures under RCP4.5 for 2021-2050 and 2051-2080 as compared to a historical baseline (1976-2005) based on the PCIP downscaled models. This data was acquired as mean data points courtesy of Climate Atlas (2018).

COLDEST MINIMUM TEMPERATURE

Projected average minimum temperatures under RCP4.5 and RCP8.5 are shown in Figure 5-12. Under both scenarios, minimum annual temperatures increase (i.e. getting warmer). RCP8.5 shows an average increase from -9.5°C during the historic baseline period (1976-2005) to -6.4°C at the end of the century (2051-2080). This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above. Minimum temperatures on individual days may be colder than these values.

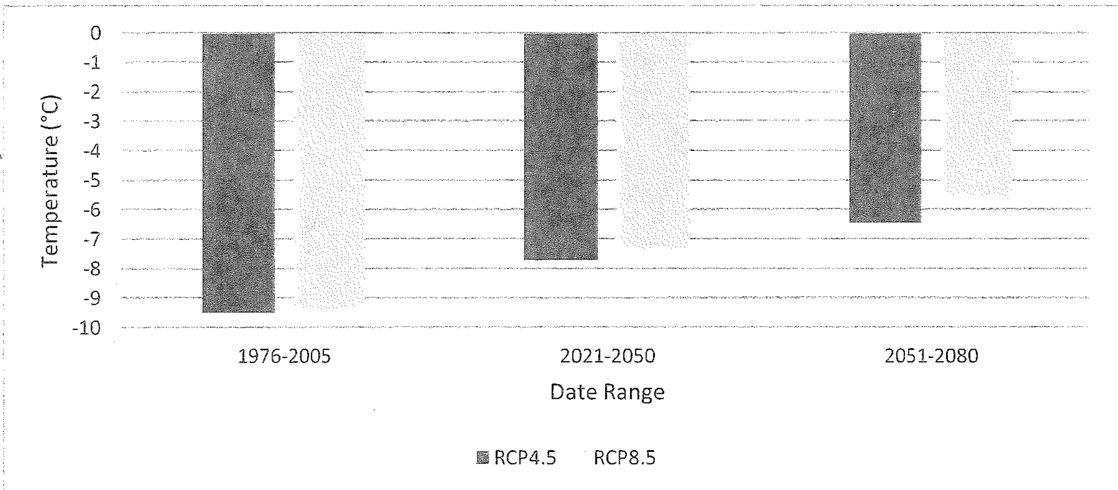

Figure 5-12 Projected average coldest minimum annual temperature under RCP4.5 and RCP8.5 for 2021-2050 and 2051-2080 as compared to the historic baseline (1976-2005). This data was acquired as mean data points courtesy of Climate Atlas (2018).

HISTORIC WARMEST MAXIMUM TEMPERATURE AND HEATWAVE EVENTS

The warmest historic temperatures on record for Comox Valley occurred on July 11th and 12th 1961 with temperatures reaching 34.4°C (Figure 5-13).

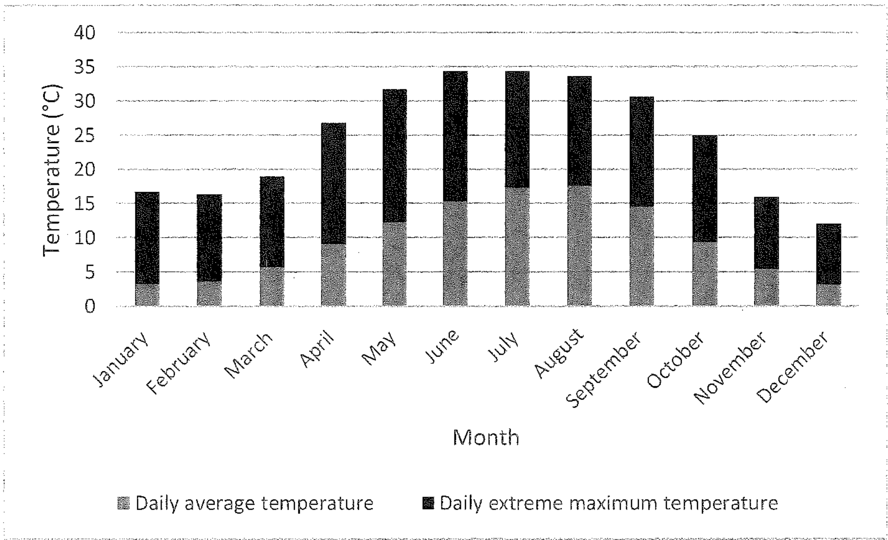

Figure 5-13 The highest historic monthly temperatures for Comox Valley by month from 1944 to August 2018 compared to historical averages. Data courtesy of Environment Canada's Historical Data Archives.

Below are examples of historic heat waves that have occurred in the Comox Valley. The events included are the most modern events in addition to the two historically highest temperatures recorded for the region. Data was accrued from news sources and verified using Environment Canada's Historical Data Archives.

- **July 1961,** Comox Valley reaches record highs of 34.4°C on July 11th and 12th. According to the available data, this record still stands.
- **June 1969,** Comox Valley reaches a one day high of 34.4°C.
- **July 2013,** A heat wave moving up from the Southwestern United States hit the Southern Coast of British Columbia, causing temperatures in Comox Valley to hit highs of 27.3°C on July 1st.
- **June 2015,** A historic weekend heat wave broke 64 temperature records including in nearby Port Alberni which saw temperatures rise to 36.6°C. Comox Valley saw temperature highs of 31.2°C.
- **August 2017,** The beginning of the month saw temperatures rise to 30°C in Comox Valley. This heat wave set a record peak demand for energy in the province, peaking at 7,500 megawatts of electricity (Johnston, 2018).
- **July 2018,** A historic heat wave hit Southern British Columbia breaking 13 previously held temperature records. Comox Valley temperatures hit a high of 32.2°C.

PROJECTED WARMEST MAXIMUM TEMPERATURE

Projected average maximum temperatures under RCP4.5 and RCP8.5 are shown in Figure 5-14. Under both scenarios, minimum annual temperatures increase (i.e. get warmer). RCP8.5 shows an average increase from 33.1°C during the historic baseline period (1976-2005) to 37°C at the end of the century (2051-2080). This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above. Maximum temperatures on individual days may be warmer than these values.

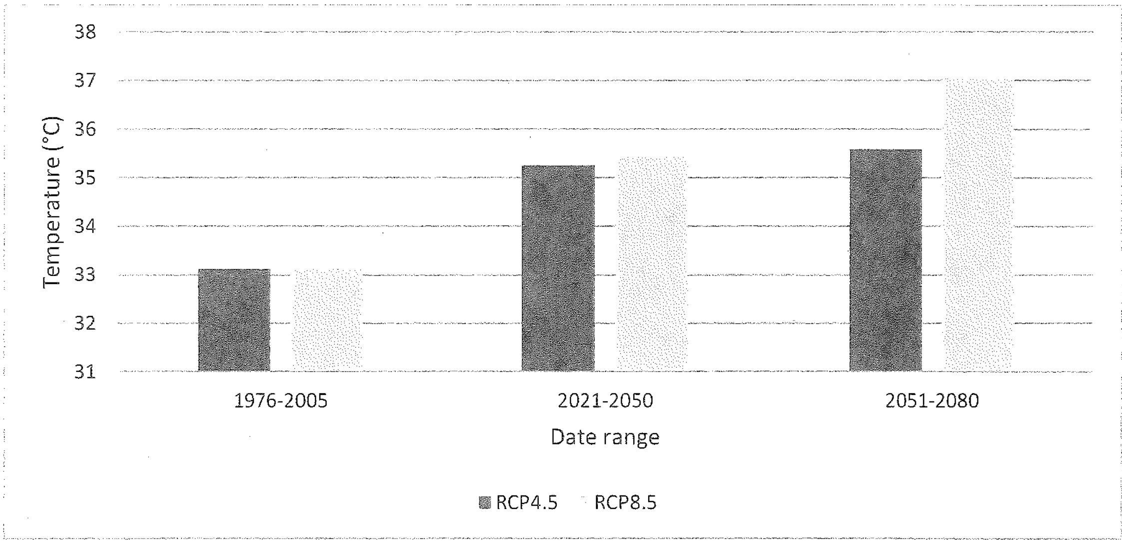

Figure 5-14 Projected average warmest maximum annual temperature under RCP4.5 and RCP8.5 for 2021-2050 and 2051-2080 as compared to the historic baseline (1976-2005). This data was acquired as mean data points courtesy of Climate Atlas (2018).

HISTORICAL GLACIAL CONDITIONS

Upper Puntledge River, a major tributary stream feeding Comox Lake, is partially fed by the Comox Glacier and the Moving Cliff Glaciers. Rising temperatures and changes in precipitation are causing the retreat of this glacial system, with some estimates predicting that the glaciers on Vancouver Island will be gone within the next 25 years (McCulloch,2014). These results are consistent with the IPCC report and recent findings which forecasts the continued widespread retreat of glaciers and ice caps through the 21st century (Clark et al., 2015).

As noted in the Comox Lake Watershed Protection Plan, the actual percentage of water to the lake supplied by glaciers is unknown and would require flow monitoring to determine (Aqua-Tex Scientific Consulting Ltd., 2016). However, the same plan states that it is well understood that wetlands, groundwater, and glacier melt together supply most of the base flow to streams during the dry summer months. In longer time scales the loss of glaciers may expose their watersheds to water shortages, while in the shorter term increased melting of glaciers may increase the volume and flow of tributaries and become a flood threat.

Comox Valley and the Comox Glacier and surrounding glacial system fall within the Nanaimo Lowland Ecosection which is included in the broader Georgia Depression Ecoprovince (Figure 5-15) (Demarchi, 2011). Between the years 1985 and 2004 the glaciers in this area have lost 34.1% of their Glacial area, greater than any of the other ecoprovinces (Environmental Reporting BC, 2016). This represents a loss of 3.3 square km of ice coverage.

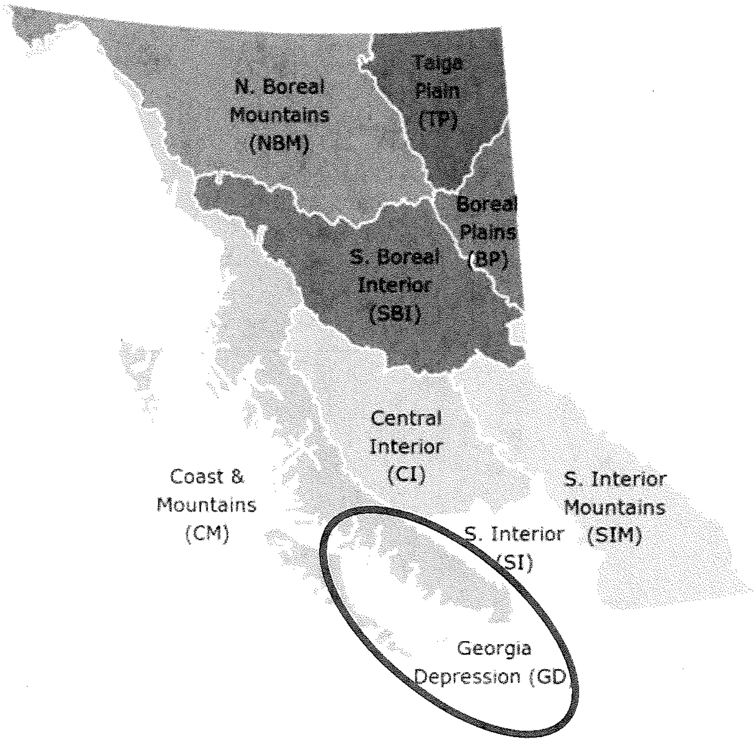

Figure 5-15 The ecoprovinces of British Columbia. The Georgia Depression where the project is located has been marked by the red circle. Image courtesy of the Government of British Columbie (2018).

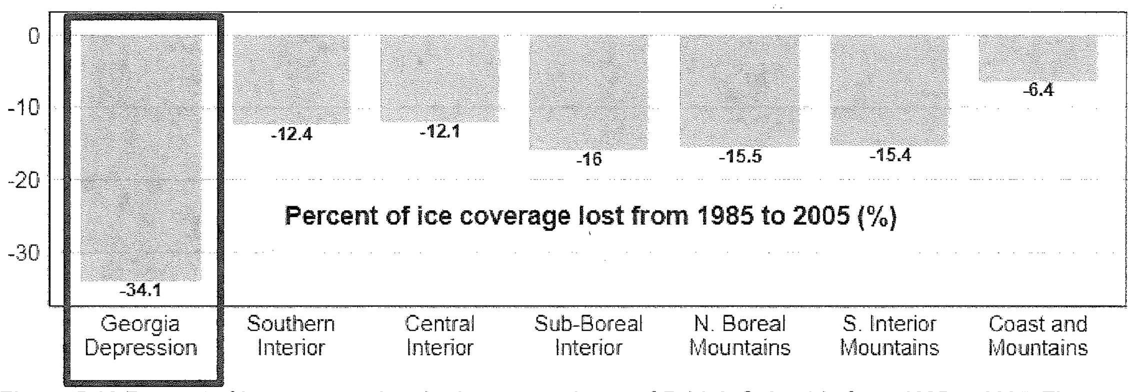

Figure 5-16 Percent of ice coverage lost in the ecoprovinces of British Columbia from 1985 to 2005. The Georgia Depression, where the project is located, is marked in red. Image courtesy of the Government of British Columbia (2018).

SOLAR RADIATION

Solar radiation baseline historic data was obtained through ClimateBC. Solar radiation projections under climate change are unavailable for this area and the impact of climate change on solar radiation levels are still being explored. As a result, and in line with global studies on solar radiation (Wild et al.,2015) an increase in solar radiation of 1% per decade is assumed to the end of the century.

Table 5-4 Baseline historic rates of solar radiation for Comox Valley (1961-1990)

Spring	Summer	Fall	Winter
14 MJ m^{-2} d^{-1}	19.5 MJ m^{-2} d^{-1}	7.6 MJ m^{-2} d^{-1}	3.8 MJ m^{-2} d^{-1}

HISTORIC SNOW AND ICE CONDITIONS

Historically, January is the month with the greatest snowfall with an average of 22.8cm, though the largest snowfall on record occurred in March 1997 with a single event producing 66.2cm of snow in one day (Figure 5-17). The months of May-August typically have no snowfall, though the extremes show that snow does sometimes fall on the shoulder months.

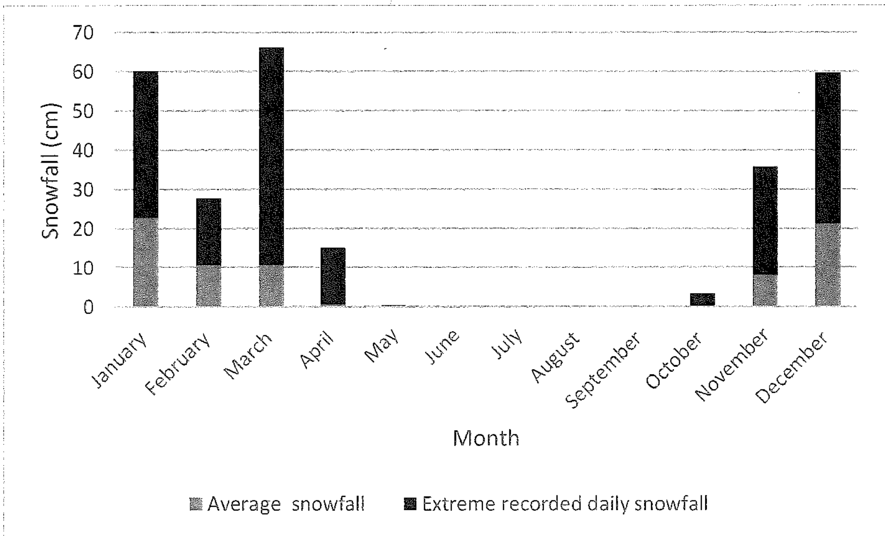

Figure 5-17 Average monthly and extreme recorded daily snowfall between 1971-2000. Data courtesy of Environment Canada Comox Historically Data.

PROJECTED SNOW AND ICE CONDITIONS

The following snow data represented in Figure 5-18 and Figure 5-19 was obtained from the Pacific Climate Impact Consortium[3]. Figure 5-18 was created by using SRES AR2 which projected a world with

[3] The information in Figure 5-18 was drawn from a set of 30 General Circulation Model (GCM) projections based on the results from 15 different GCMs. This data was created before the release of the IPCC's (Intergovernmental Panel on Climate Change) Fifth Assessment Report which introduced the RCPs (Representative Concentration Pathways) that are used dominantly in climate projections today, and in this assessment. Prior to AR5, the fourth IPCC report used different emissions scenarios as described in the Special Report on Emissions Scenarios (SRES). These SRES were scenarios which made assumptions regarding future population growth, technological advancement,

moderate economic growth, a high population increase, and regionality. This scenario uses the assumption that there will be an atmospheric concentration of carbon dioxide of approximately 1250ppm by the end of the century. While effective, these scenarios did not incorporate carbon emissions controls which is why they were replaced with the RCPs.

Figure 5-18 shows a projected decrease in snowfall on Vancouver Island, where the proposed WTP will be located, of close to 60% of current conditions by the end of the century.

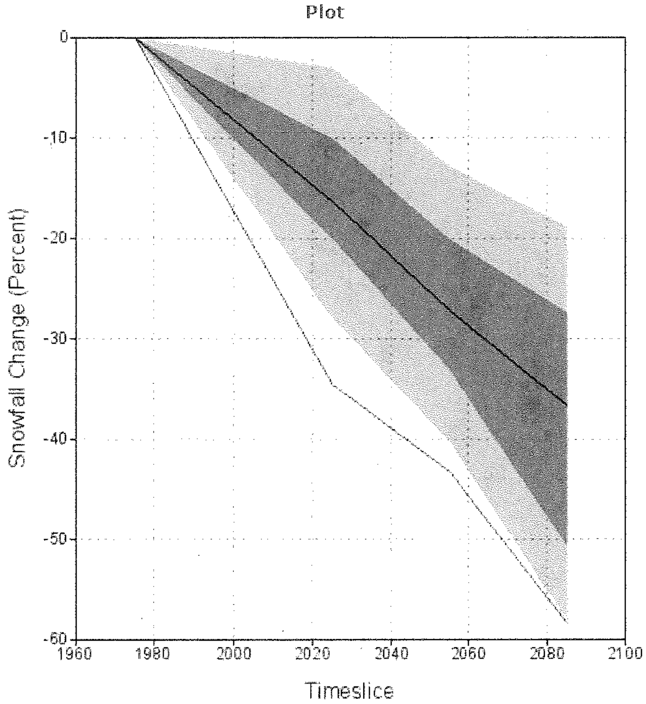

Figure 5-18 Projected annual precipitation falling as snow over Vancouver Island under the AR2. The black line indicates the median of the data set, the dark grey highlights the 25th to 75th percentiles, and the light grey indicates the 10th to 90th percentiles. The blue line indicates the CGM3 A2 run 4, used for display purposes. Image courtesy of Neinaber and Bronaugh (2012).

Figure 5-19 shows a single projection from the ensemble GCMs (CGM3 A2 run 4) which was developed by Environment Canada's Canadian Centre (ECCC) for Climate Modelling and Analysis, of annual precipitation falling as snow[4]. The model used baseline historic weather data from 1961-1990 and projects to the years 2050. End of the century projections were not available.

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globalization, and societal values in order to predict future GHG concentrations to use as bases in modeling (IPCC. 2007).

[4] This model data was downscaled into a higher resolution with ClimateBC's empirical downscaling tool which uses interpolation, elevation corrected temperature and the Parameter-elevation Regressions on Independent Slopes Model (PRISM) 4km high-resolution climatology derived from multiple regression of weather station data against topographical features. This allows for the high-resolution estimates of projected climate data seen below.

Figure 5-19 shows a decrease in annual precipitation as snow for Vancouver Island for the year 2050 compared to the historical average.

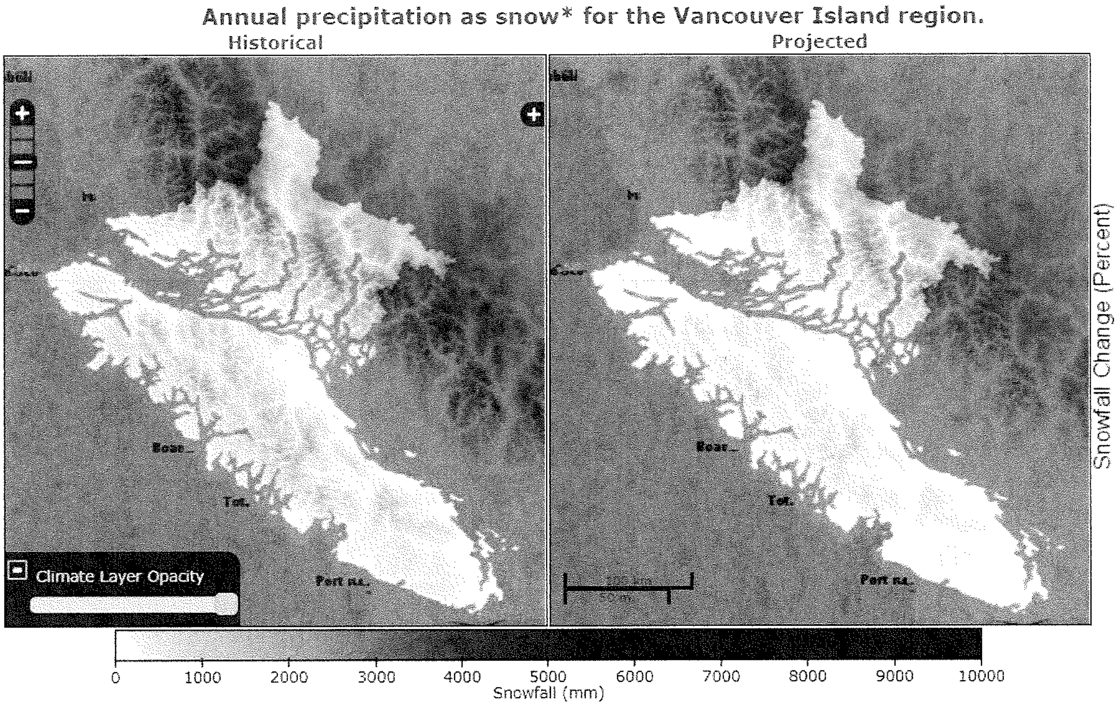

Figure 5-19 Annual precipitation as snow for the Vancouver Island region projected using CGM3 A2 run 4 for the year 2050 (right) compared to historical baseline data (1961-1990) (left). Image courtesy of Neinaber and Bronaugh (2012).

ANNUAL ICING DAYS

Icing days are the days per year on which air temperature does exceed 0°C. This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above.

Figure 5-20 shows a projected decrease in icing days for both RCPs. RCP4.5 projects a decrease in the number of icing days from 2.7 during the historical baseline (1976-2005) to 0.8 icing days in the middle of the century (2021-2050) to 0.3 icing days at the end of the century (2051-2080). RCP8.5 projects a similar pattern, with a decrease from 2.7 (1976-2005) to 0.4 icing days (2021-2050) to only 0.3 icing days at the end of the century (2051-2080).

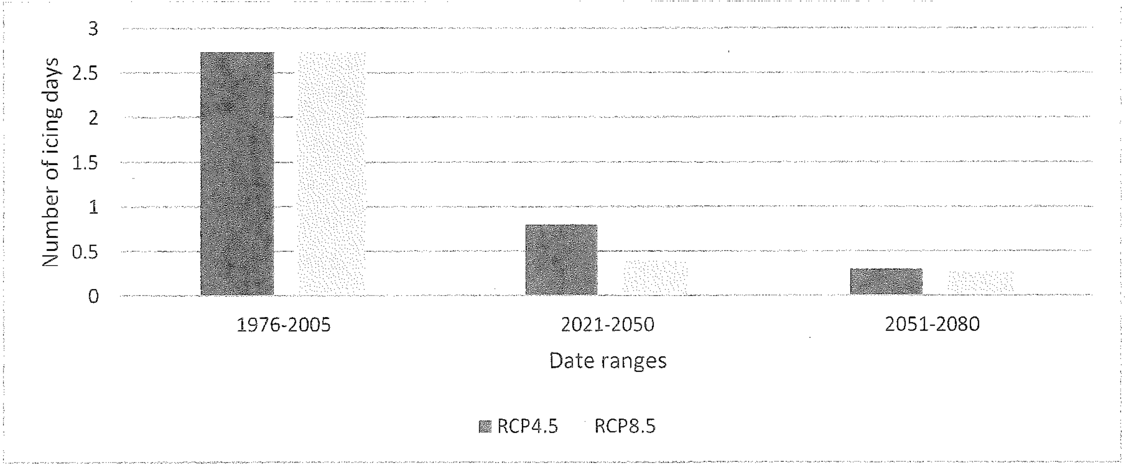

Figure 5-20 Projections of icing days (days in which the temperature remains below 0°C) for 2021-2050 and 2051-2080 compared to a historic baseline of 1976-2005 based on the PCIP downscaled models. This data was acquired as mean data points courtesy of Climate Atlas (2018).

ANNUAL FREEZING DEGREE DAYS

Freezing degree days (FFDS) are a measure of how cold it has been and how long it has been cold. It is calculated as the sum of the average daily degrees below freezing for a specific time period. This projection data was acquired from PCIP through Climate Atlas and represents the mean of the ensemble of downscaled models listed above. Under RCP4.5 FFDs are projected to decrease from 28.2 per year for the historic baseline period (1976-2005) to 11.1 mid-century (2021-2050) and 5.8 at the end of the century (2051-2080).

RCP8.5 shows similar trends, with a projected decrease from 28.2 during the historic baseline to 8.9 mi-century and 3.2 at the end of the century. FDDs are good indicators of the severity and length of a winter, and the projected declines suggest milder and shorter winter conditions.

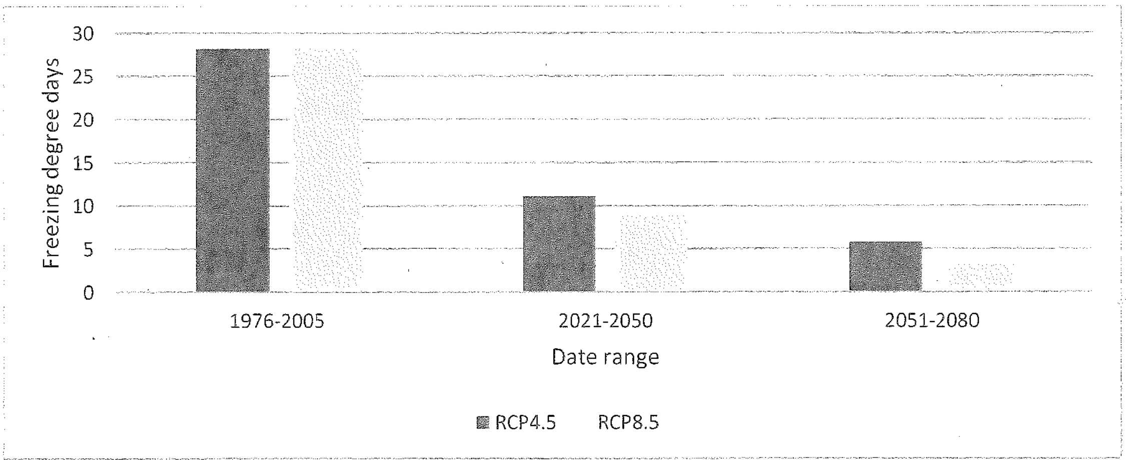

Figure 5-21 Projections of freezing degree days for 2021-2050 and 2051-2080 as compared to a baseline of 1976-2005 based on the PCIP downscaled models. This data was acquired as mean data points courtesy of Climate Atlas (2018).

WIND

HISTORICAL WIND CONDITIONS

Historically, the windiest month in Comox Valley is December, with an average wind speed of 14km/hr as averaged from 1985 to 2015 data. Figure 5-22 shows monthly average wind speeds compared to the maximum recorded sustained wind speeds (1 minute averages). The maximum recorded historic wind gusts for Comox Valley hit 89km/hr during April.

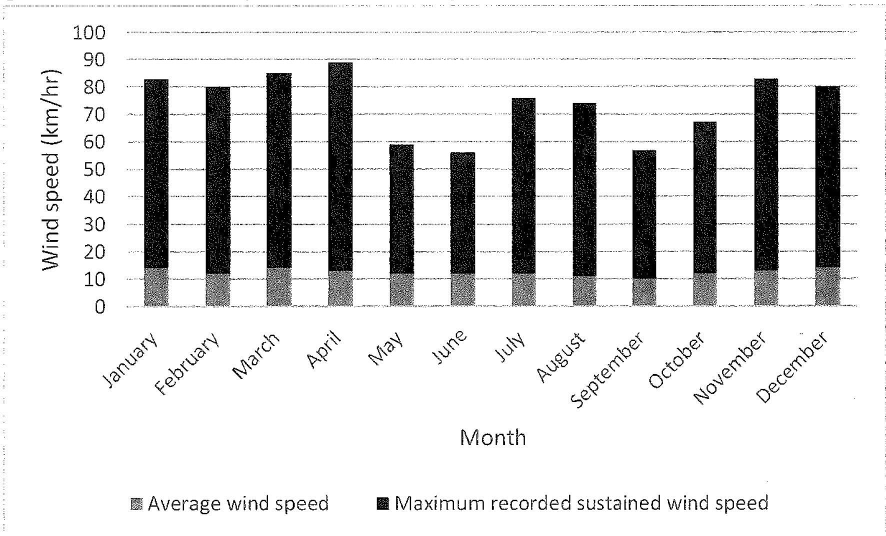

Figure 5-22 Comox Valley historical average monthly wind speeds from 1953-2018. These represent the average sustained wind speeds (greater than 1 minute). Data Courtesy of Environment Canada.

PROJECTED WIND CONDITIONS

While the ECCC has conducted a national-level projection for future near surface wind conditions, the coarse (spatial) resolution and lack of regional observations has meant that wind has not been considered here. As a result, a precautionary approach has been adopted in the exposure ratings listed in Table 5-5 and a Medium exposure rating applied.

HISTORIC STORM EVENTS

Below is a summary of recent storm events which took place in Comox Valley:

- **March 12th, 2012** Winds reaching over 110km/hr left over 78,000 BC Hydro customers on Vancouver Island without power and forced the shutdown of schools in Comox Valley.
- **December 9th, 2014** Comox Valley and nearby Alberni Valley are inundated with over 200mm of snow over three days, a state of emergency was declared, and over 15,000 people lost power.
- **March 10th, 2016** High winds and 70mm of rain caused localized flooding in Comox Valley, 118,000 BC Hydro customers lost power along British Columbia's South Coast.
- **February 9th, 2017** 26cm of snow fell in Comox Valley, leaving over 13,000 homes without power on Vancouver Island.
- **January 20th, 2018,** 148mm of precipitation fell in 24 hours resulting in swelling of the Puntledge and Cruikshank's rivers and causing localized flooding.

PROJECTED STORM EVENTS

Figure 5-6 in the precipitation section suggests an increase in heavy precipitation days (those with greater than 20mm of rain) with a projected increase of 3.4 event days per year from the historical baseline (1976-2005) to the end of the century (2051-2080). There is no readily available extreme storm event projection data for this region, however, in general the IPCC AR5 predicts that a changing climate will lead to changes in frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events. As a result, and owing to recent historical events that have caused significant damage and disruption in the region, a precautionary approach has been adopted in the exposure ratings listed below (see Table 5-5) and a Medium exposure rating applied.

EVAPORATION

Figure 5-24 shows the projected Heagreaves evaporation rates for the years 2055 and 2085 compared to a historical baseline (1971-2000) for RCP8.5 and RCP4.5, respectively. Heagreaves evaporation is derived from an equation which considers maximum and minimum air temperature, and solar radiation to determine reference evapotranspiration. This data is sourced from ClimateBC, a program which downscales the general circulation models from IPCC AR5 to calculate climate variables based on latitude, longitude, and elevation.

Evaporation for Comox Valley is predicted to increase under both RCPs notably in the spring and summer, with minimal increases in the winter and fall. Under RCP8.5 the largest change in evapotranspiration is projected to occur in summer with an increase of 94mm from 331mm during historic baseline years (1976-2005) 425mm at the end of the century (2051-2080). This represents an increase of 28% during that period. Under RCP4.5 the largest change is projected for the spring season, with an increase of 66mm from baseline to end of century data, a 33.4% increase in the amount of evapotranspiration.

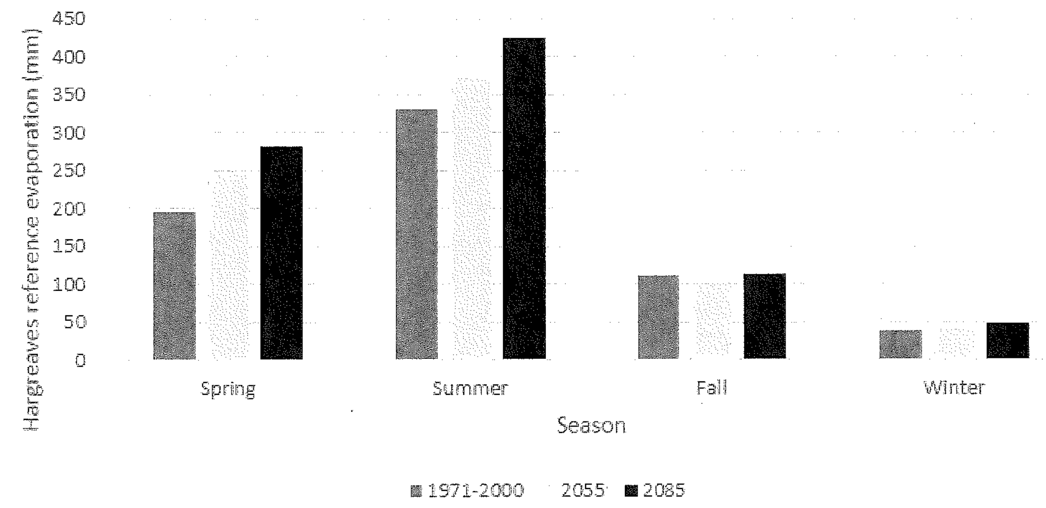

Figure 5-23 Projected average Heagreaves evaporation rates for years 2055 and 2085 as compared to a historic baseline (1971-2000) under RCP8.5 based on the PCIP downscaled models. This data was acquired as mean data points.

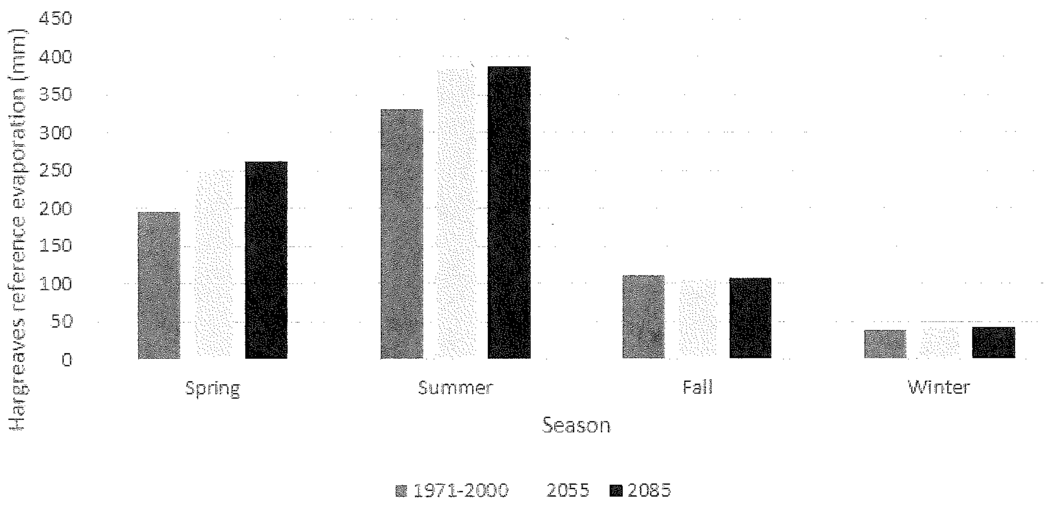

Figure 5-24 Projected average Heagreaves evaporation rates for years 2055 and 2085 as compared to a historic baseline (1971-2000) under RC4.5 based on the PCIP downscaled models. This data was acquired as mean data points.

SOIL

MOISTURE

Appendix B-1 shows soil moisture map of Comox Valley indicating current areas of soil moisture deficit and excess water. The areas surrounding the Project are largely soil moisture deficient with isolated areas of excess moisture. Soil moisture deficiency is characterized in an agricultural context as soil requiring irrigation while excess moisture requires draining.

Global projections of soil surface (upper 10cm), total soil moisture, and soil moisture integrated down to 3m were determined using 25 models from the CMIP5 ensembles projected to the years 2070-2099 under RCP8.5 with a historic baseline of 1976-2005 conditions (Figure 5-25). For all three variables, western British Columbia is projected to have either a mean decrease in soil moisture or no change in soil moisture.

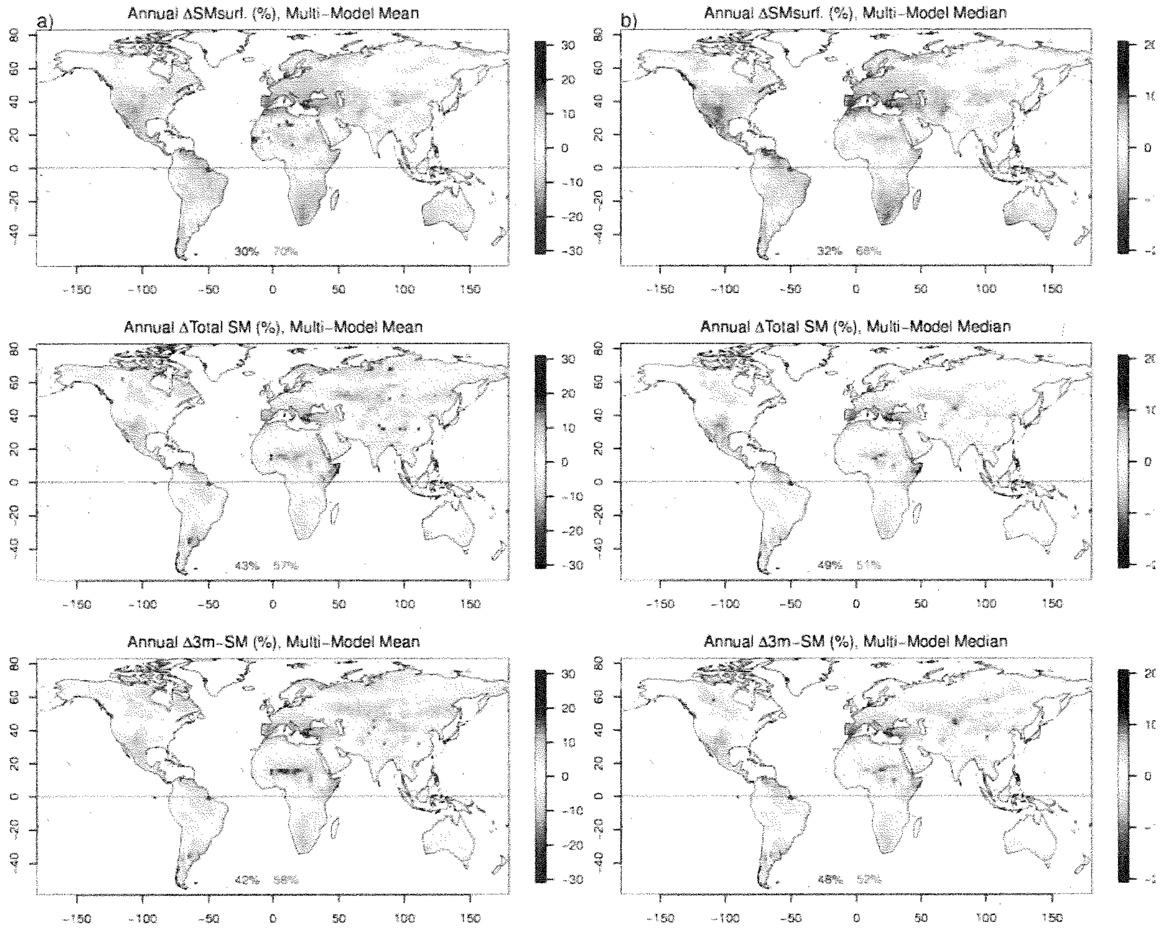

Figure 5-25 Soil moisture data - (a) Multi-model annual mean change between a baseline of 1976-2005 and projected values of 2070-2099 using RCP8.5 of (top to bottom) surface (upper 10CM) soil moisture, total soil moisture, and soil moisture integrated down to 3 meters. Values are percentages of simulated present-day values. (b) same as (a) with multi-model median. Number indicate the share of the land surface with positive (blue) or negative (red) changes. Data courtesy of Berg et al. (2017).

SALINITY, RUNOFF, STABILITY

Salt intrusion data is not readily available for this region. However, salt intrusion is anticipated to be minimal due to the elevation of the project site and Comox Lake, and the distance from the coast, as noted above.

Soil runoff and stability data are not readily available for this region, and have not been considered in this section. However, soil runoff and stability are heavily influenced by precipitation and temperature conditions which have been previously discussed in this document. Current and future precipitation conditions and projections have been discussed in the precipitation section and trends have been illustrated in Figure 5-3, Figure 5-4 and Figure 5-6. Temperature has also been considered and the information illustrated in Figure 5-10 and Figure 5-11. In summary, soil runoff and stability are partially

dependent on the relationship between precipitation, temperature, erosion, and vegetation. An increase in temperature without an increase in precipitation which results in drought conditions and decreases in vegetation may increase erosion rates. Conversely, an increase in temperature and precipitation may increase vegetative cover and decrease erosion rates, increasing stability, and reducing runoff. In addition, an increase in heavy precipitation and storm events or wind events may increase soil erosion and decrease stability. As seen in Figure 5-25, surface soil moisture is projected to decrease for this region, potentially making it more susceptible to soil erosion (note Figure 5-25 is global data and may not accurately reflect projected soil moisture content for individual areas). In addition, as glaciers retreat the runoff per unit area from glaciers increases, though the total glacier contribution to sediment and runoff in a basin may decline with reduction in glacier area (Robin et al., 2010).

PH

SOIL

Due to a lack readily available data or projections of soil pH in Comox Valley, an analysis of exposure to changes has not been conducted for this variable. However, as noted above, exposure to salt intrusion are not anticipated to affect the proposed project due to elevation and distance from the coast.

HISTORICAL FRESH WATER

Figure 5-26 and Figure 5-27 shows the daily fluctuations in source water pH for 2016 and 2017 obtained from the Comox Valley Water Systems water quality reports. The mean pH values for these years were 7.7 and 7.39 respectively, well within operational boundaries of 7.0 to 8.5 (Comox Valley Regional District, 2017). These are the only years for which pH data was readily available; a longer-term record would allow for historic changes in pH to be identified.

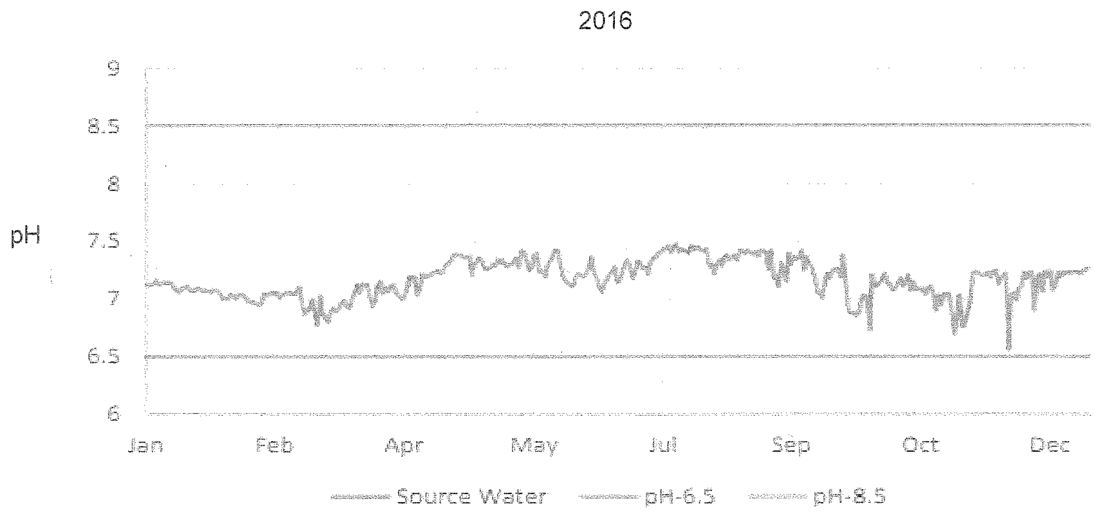

Figure 5-26 2016 Comox Valley source water pH obtained from the Comox Valley Water Systems 2016 water quality report (Comox Valley Regional District, 2016).

Figure 5-27 2017 Comox Valley source water pH obtained from the Comox Valley Water Systems 2017 water quality report (Comox Valley Regional District, 2017).

PROJECTED FRESHWATER PH

Projecting how climate change will impact the pH of any given Lake is difficult because in addition to climate factors such as precipitation and temperature, geographic features such as land cover, lithology, and even elevation play an important role. A 2015 paper by Strange and Ahern considers the potential influence of climate change on the acid-sensitivity of high elevation lakes in the Georgia Basin where the project site is located. The study took the water and soil conditions of fifty-four high level lakes in the area and ran a redundancy analysis to determine which variables were heavily influenced by climate. The paper suggests that the pH of lakes in this area are influenced by the amount of ice and glacier, with higher pH's in areas dominated by glacial catchments. An initial increase in glacial meltwater from increasing temperatures could increase the pH of Comox Lake, which is partially glacier fed, followed by a decrease if the glacier disappears. Receding glaciers also expose greater areas of land to physical and chemical weathering, which in tandem with increased temperatures and precipitation rates, have been directly linked to the increased transport of base cations and other solutes from catchments to surface water. The paper concluded that whether pH decreases or increases is dependent on if the increase in base cations are sufficient to buffer against an increase in acidity from atmospheric sources.

In addition, a study using paleoclimate data noted that air temperature was a large determining factor of lake pH through the past 200 years due to the interaction of the physico-chemical condition and biota of the lake and the duration of ice and snow cover, weathering rates, water-retention times, delayed freezing and ice-out dates which impact the natural cycles of the lake. This study pointed to the temperature increases of climate change as the primary cause for shifts in high Alpine lakes (Koinig et al., 1998). While Comox Lake did not appear directly in either of these studies, they can be used to estimate exposure of the watershed to pH changes as Comox Lake is partially glacier fed and is expected to see increased in both precipitation and temperature, which could shift its pH (Koinig et al.,1998).

CLIMATE EXPOSURE RATING

Based on the information described above, literature review, and expert opinion, Table 5-5 and Table 5-6 outline the climate exposure ratings for the Project during construction and operation and maintenance, respectively.

The exposure ratings are defined as:

- High exposure (red): Climate variable inflicts significant exposure;
- Medium exposure (orange): Climate variable inflicts some exposure, and
- Low exposure (green): Climate variable inflicts little or no exposure.

Table 5-5 Climate Exposure Rating (Construction)

Climate Variable	Exposure Theme	Justification/Evidence	Exposure
Sea	Change in sea level	Limited exposure during construction phase.	Low
	Storm surge and storm tide	Limited exposure during construction phase.	Low
Precipitation	Change in average rainfall	Limited exposure during construction phase.	Low
	Drought	Limited exposure during construction phase.	Low
	Extreme rainfall events (flooding)	Historical flooding events have affected the area and projections suggest an increase in heavy precipitation days under both RCPs.	Medium
	Changes in source lake water levels	Limited exposure during construction phase but could require relocation of intake on Lake Comox. More detailed study is required.	Medium
Temperature	Change in average temperature	Limited exposure during construction phase.	Low
	Extreme temperature events	Historical records show peak temperatures of 34.4°C.	Medium
	Glaciers	Limited exposure during construction phase.	Low
	Solar radiation	Limited exposure during construction phase.	Low
	Snow and ice	Evidence of a decrease in icing days and average snowfall, also supported by projections.	Medium
Wind	Gales and extreme wind events	Using a precautionary approach, high wind speeds and extreme wind events are assumed pending further information and analysis.	Medium
	Storms (snow, hail, dust and lightning)	There have been recent storms that have caused damage, flooding and power outage.	Medium

Climate Variable	Exposure Theme	Justification/Evidence	Exposure
		Although there is uncertainty in projecting changes in storms, projections suggest an increase in storm frequency and severity.	
Evaporation	Change in annual average	Limited exposure during construction phase.	Low
Soil	Moisture	Limited exposure during construction phase.	Low
	Salinity	Limited exposure during construction phase.	Low
	Runoff	Limited available historical (and projected) runoff data available. However, historical evidence of flash flooding events and projected increases in heavy precipitation days (and storms) require a precautionary approach to be applied.	Medium
	Stability	Limited exposure during construction phase.	Low
pH	Soil	Limited exposure during construction phase.	Low
	Fresh water	Limited exposure during construction phase.	Low

Table 5-6 Climate Exposure Rating (Operation & Maintenance)

Climate Variable	Sensitivity theme	Justification/Evidence	Exposure
Sea	Change in sea level	The elevation of the site, located at 140m above sea level, limits its exposure to sea level rise.	Low
	Storm surge and storm tide	Limited exposure to storm surge due to elevation.	Low
Precipitation	Change in average rainfall	Projected increase of 92mm in fall and 83mm in winter (RCP8.5) above baseline levels.	High
	Drought	Projections suggest increased soil moisture conditions in the region but precipitation projections suggest a decrease in summer – therefore seasonality could be an issue and exposure to drought is possible.	Medium
	Extreme rainfall events (flooding)	Expected increase in the number of heavy precipitation days by 3.7 days per year by 2100 (RCP8.5).	Medium

Climate Variable	Sensitivity theme	Justification/Evidence	Exposure
	Changes in source lake water levels	Increased glacier melt, increased temperatures and increased (spring/winter/fall) precipitation suggest that water levels could be affected on Comox Lake.	Medium
Temperature	Change in average temperature	Limited exposure to changes in average temperature. RCP8.5 suggests an increase in seasonal temperatures of ~3°C in summer.	Low
	Extreme temperature events	Projected maximum daily mean temperature rise of +3.9°C by 2100 (RCP8.5). Individual days will likely exceed this level and will contribute to glacial melt.	Medium
	Glaciers	Existing glacier is in retreat phase and increased temperature is likely to contribute to this trend.	High
	Solar radiation	Local projections are not available, although global studies suggest a 1% per decade increase, suggesting that exposure to changes in solar radiation is limited.	Low
	Snow and ice	Projections suggest both a decrease in snowfall and the number of icing days (days <0°C) and freezing degree days owing to increased temperature. These changes could lead to increased melt and inputs to Lake Comox.	Medium
Wind	Gales and extreme wind events	Limited projections are available. Global studies suggest a minor increase in mean windspeeds but more severe gales. A precautionary approach has been adopted.	Medium
	Storms (snow, hail, dust and lightning)	There have been recent storms that have caused damage, flooding and power outage. Limited projections are available. Global and regional studies suggest an increase in both the severity and frequency of storms.	Medium
Evaporation	Change in annual average	Projections suggest an increase in evaporation in spring and summer (greatest under RCP8.5 – from 331mm to 425mm by 2100), and minimal increases in fall and winter.	Medium
Soil	Moisture	Projections suggest that the area will either experience no change in soil moisture or that	Low

Climate Variable	Sensitivity theme	Justification/Evidence	Exposure
		soil moisture content will decrease with isolated areas of excess moisture.	
	Salinity	Salt intrusion is projected to be minimal due to elevation of the project site and distance from the coast.	Low
	Runoff	Limited projections are available. Runoff is heavily influenced by precipitation and temperature which suggests an increase in extreme surface water runoff events. Precautionary approach adopted.	Medium
	Stability	As above, limited projections are available. Stability is heavily influenced by precipitation and temperature which suggests an increase in extreme runoff events. Also, as noted above, the persistence of drought and SMD could be an issue. A precautionary approach has been adopted.	Medium
pH	Soil	Limited exposure to pH change from salt water intrusion due to site location/elevation, as noted in sea section.	Low
	Fresh water	Drought exposure is likely (see drought section above) but exposure of the Comox Lake is limited. No available projections of changes in pH are available but the Project's location also limits exposure.	Low

5.2.3 PROJECT VULNERABILITY RATING

The sensitivity and exposure assessments have been combined to provide an overall assessment of vulnerability of the Project using the rating matrix shown in Appendix A-1. Table 5-7 and Table 5-8 present the overall assessment of vulnerability for the Project during the construction and operation and maintenance phases, respectively.

Table 5-7 Vulnerability Rating Matrix (Construction)

Phase	Climate Variable	Sensitivity/Exposure Theme	Sensitivity	Exposure	Vulnerability
Construction	Sea	Change in sea level	Low	Low	Low
		Storm surge and storm tide	Medium	Low	Low
	Precipitation	Change in average rainfall	Low	Low	Low
		Drought	Low	Low	Low
		Extreme rainfall events (flooding)	Medium	Medium	Medium
		Changes in source lake water levels	Low	Medium	Low
	Temperature	Change in average temperature	Low	Low	Low
		Extreme temperature events	Medium	Medium	Medium
		Glaciers	Low	Low	Low
		Solar radiation	Low	Low	Low
		Snow and ice	Medium	Medium	Medium
	Wind	Gales and extreme wind events	Medium	Medium	Medium
		Storms (snow, hail, dust and lightning)	Medium	Medium	Medium
	Evaporation	Change in annual average	Low	Low	Low
	Soil	Moisture	Medium	Low	Low
		Salinity	Low	Low	Low
		Runoff	Low	Medium	Low
		Stability	Medium	Low	Low
	pH	Soil	Low	Low	Low
		Fresh water	Low	Low	Low

Table 5-8 Vulnerability Rating Matrix (Operation and Maintenance)

Phase	Climate Variable	Sensitivity/Exposure Theme	Sensitivity	Exposure	Vulnerability
Operation and Maintenance	Sea	Change in sea level	Medium	Low	Low
		Storm surge and storm tide	Medium	Low	Low
	Precipitation	Change in average rainfall	Medium	High	Medium
		Drought	High	Medium	Medium
		Extreme rainfall events (flooding)	High	Medium	Medium
		Changes in source lake water levels	High	Medium	Medium
	Temperature	Change in average temperature	Medium	Low	Low
		Extreme temperature events	High	Medium	Medium
		Glaciers	High	High	High
		Solar radiation	Low	Low	Low
		Snow and ice	Medium	Medium	Medium
	Wind	Gales and extreme wind events	Medium	Medium	Medium
		Storms (snow, hail, dust and lightning)	Medium	Medium	Medium
	Evaporation	Change in annual average	Medium	Medium	Medium
	Soil	Moisture	Medium	Low	Low
		Salinity	Medium	Low	Low
		Runoff	Low	Medium	Low
		Stability	Medium	Medium	Medium
	pH	Soil	Low	Low	Low
		Fresh water	Medium	Low	Low

Based on the assessment provided above, Medium and High vulnerabilities will be taken forward into the detailed risk assessment phase (Phase 2) of the Climate Change Resilience Assessment.

These vulnerabilities are expected to pose material risks such as flooding or damage to infrastructure during extreme weather events, and impacts to operations caused by changes to turbidity levels, water quality and water availability. Phase 2 of the assessment will provide a risk assessment to identify and evaluate risks to the Project, incorporate actions taken by the Project to mitigate these risks, and explore other mitigating actions to reduce climate risks to a manageable level prior to construction.

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A RATING MATRICES

A-1 VULNERABILITY TABLES

SENSITIVITY MATRIX EXAMPLE

Phase	Variable	Type	Project element(s)	
			WTPs	Sewerage networks
Construction	Temperature	Mean monthly temperature	Low	N/A
		Extreme temperature events	Medium	
	Precipitation	Mean monthly precipitation	Medium	Low
		Extreme precipitation events	High	High
		Drought	High	Medium
	Etc.	etc	etc	etc

Repeat for operation and maintenance
High sensitivity (red): Climate variable/hazard may have a significant impact;
Medium sensitivity (orange): Climate variable/hazard may have a slight impact;
Low sensitivity (green): Climate variable/hazard has little effect; and
N/A (white): Climate variable/hazard screened out.

EXPOSURE MATRIX EXAMPLE

Phase	Variable	Type	Project element(s)	
			WTPs	Sewerage networks
Construction	Temperature	Mean monthly temperature	Low	
		Extreme temperature events	Medium	
	Precipitation	Mean monthly precipitation	Medium	
		Extreme precipitation events	High	
		Drought	High	
	Etc.	etc	etc	

Repeat for Operation and Maintenance phases.
High exposure (red): Climate variable inflicts significant exposure;
Medium exposure (orange): Climate variable inflicts some exposure, and
Low exposure (green): Climate variable inflicts little or no exposure.

VULNERABILITY RATING MATRIX EXAMPLE

Sensitivity	Exposure		
	Low	**Medium**	**High**
Low	Low	Low	Low
Medium	Low	Medium	Medium
High	Low	Medium	High

A-2 RISK TABLES

ESTIMATES OF LIKELIHOOD OF RISKS

Probability range Type of event	Very Low	Low	Moderate	High	Very High
Significant single event; or	Not likely to occur in period	Likely to occur once between 30 and 50 years	Likely to occur once between 10 and 30 years	Likely to occur at least once a decade.	Likely to occur once or more annually
Ongoing/ Cumulative occurrence	Not likely to become critical/ beneficial in period	Likely to become critical/ beneficial in 30-50 years	Likely to become critical/ beneficial in 10-30 years	Likely to become critical/ beneficial in a decade	Will become critical/ beneficial in several years

ESTIMATES OF CONSEQUENCES OF RISK

Factor Degree	Adaptive capacity	Infrastructure	H&S	Governance	Financial	Social	Environmental	Economy	Reputation
Very Low									
Low									
Moderate									
High									
Very High									

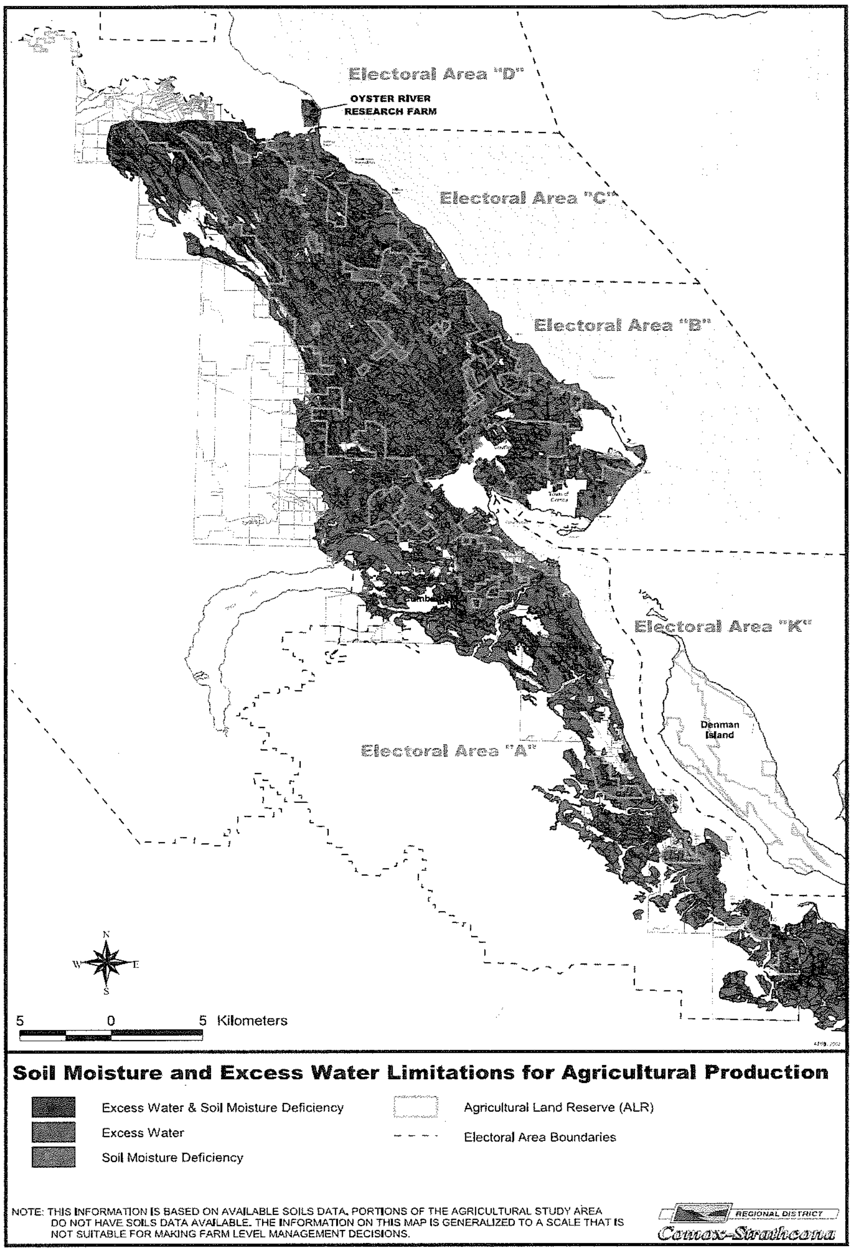
RISK RATING MATRIX

Consequence	Likelihood				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
Very Low	Negligible	Negligible	Low	Low	Moderate
Low	Negligible	Low	Low	Moderate	High
Moderate	Low	Low	Moderate	High	High
High	Low	Moderate	High	High	Extreme
Very High	Moderate	High	High	Extreme	Extreme

Extreme Risk: Immediate controls required
High Risk: High priority control measures required
Moderate Risk: Some controls required to reduce risks to lower levels
Low Risk: Controls likely not required
Negligible Risk: Risk events do not require further consideration

B SUPPLEMENTARY MATERIAL

B-1 SOIL MOISTURE AND EXCESS WATER LIMITATIONS FOR AGRICULTURAL PRODUCTION IN COMOX VALLEY

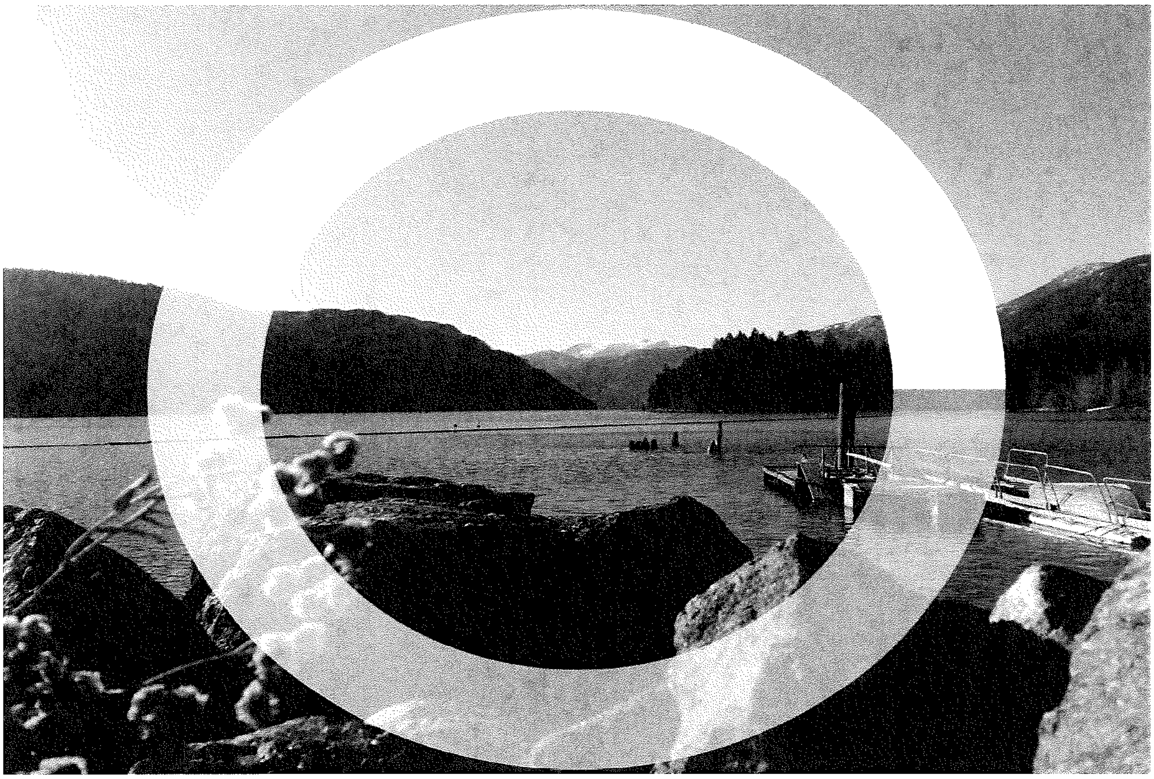


COMOX VALLEY WATER TREATMENT PROJECT

CLIMATE LENS ASSESSMENT

PHASE 2 - CLIMATE CHANGE RESILIENCE ASSESSMENT

OCTOBER 23, 2018



CLIMATE LENS ASSESSMENT

PHASE 2 - CLIMATE CHANGE RESILIENCE ASSESSMENT

COMOX VALLEY WATER TREATMENT PROJECT

FINAL REPORT

DATE: OCTOBER 23, 2018

SIGNATURES

PREPARED BY

October 23, 2018

Date

October 23, 2018

Date

October 23, 2018

Date

APPROVED BY

October 23, 2018

Date

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1 ATTESTATION OF COMPLETENESS

We the undersigned attest that this Resilience Assessment was undertaken using recognized assessment tools and approaches (i.e. ISO 31000: 2009 Risk Management – Principles and Guidelines) and complies with the General Guidance and any relevant sector-specific technical guidance by Infrastructure Canada for use under the Climate Lens.

Prepared by: ______________________ Date: October 23, 2018

______________________ Date: October 23, 2018

______________________ Date: October 23, 2018

Validated by: ______________________ Date: October 23, 2018

2 EXECUTIVE SUMMARY

PROJECT OVERVIEW

was commissioned by the Comox Valley Regional District (CVRD) to conduct a Climate Lens assessment for the Comox Valley Water Treatment Project (the Project). The Climate Lens consists of two elements: a GHG Mitigation Assessment and a Climate Change Resilience Assessment. This report provides the detailed assessment phase (Phase 2) of the Climate Change Resilience Assessment. A separate report is available for the GHG Mitigation Assessment and the Phase 1 Preliminary Climate Change Resilience Assessment.

The Project consists of the construction of a new Comox Lake water intake, raw water pump station (RWPS), filtration water treatment plant (WTP) with direct filtration and UV disinfection, and additional buried conveyance piping. New components will integrate with existing infrastructure including downstream conveyance piping, as well as emergency back-up pumping station and chlorination facility. The Project may also re-use two UV disinfection reactors currently housed in the chlorination facility and will remove the existing water supply connection from a BC Hydro penstock.

The Project will provide safe drinking water for the region. CVRD commissioned the Project in response to a directive from the Vancouver Island Health Authority (Island Health) to provide filtration as part of their water treatment system. The Project will satisfy this Directive and bring CVRD into compliance with the British Columbia *Drinking Water Protection Act.*[1]

PHASE 2 ASSESSMENT METHODOLOGY

The Climate Change Resilience Assessment has been divided into two phases. The Phase 1 assessment consisted of a climate sensitivity analysis and climate exposure analysis, culminating in an assessment of climate vulnerability for the Project. Phase 1 provided a background of the project and relevant climate change and weather-related impacts and identified several Medium and High classification vulnerabilities. This report, documenting the Phase 2 assessment, builds off the Phase 1 report and consists of a risk analysis of the climate and weather-related risks for the project.

RISK ANALYSIS & EVALUATION

Risks and opportunities associated with current and projected climate and weather-related impacts were identified for the Project. The assessment included a list of 28 risks and two (2) opportunities. For each risk and opportunity, a likelihood and consequence rating were determined. The likelihood rating was developed from the projected climate data and historic instances of events and weather conditions compiled in Phase 1. The average consequence rating of each risk and opportunity was determined by averaging eight (8) types of consequences or themes, including economic, environmental and health and

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[1] Government of British Columbia, Drinking Water Protection Act, Chapter 9 (SBC 2011).

safety related consequences. The likelihood and consequence ratings were combined to create an initial risk rating for each of the risks and opportunities.

The initial risk ratings referred to the risk without any form of mitigation or control measure. Of the risks examined, 6 were ranked High, 12 Moderate, and 10 Low or Negligible. The High and Moderate risks, if not mitigated by the Project, could lead to damage to infrastructure, water quality and availability impacts, disruption to operations and service delivery, and other impacts.

RISK MITIGATION & RESIDUAL RISK

Control measures included in the design or planned operations of the Project were identified and their effectiveness examined. In assessing the adequacy of control measures, the effectiveness of the planned control measures at reducing the consequences of the risk was expressed. All control measures included in the Project were determined to be adequate or optimal. Residual risk ratings, capturing the remaining risk after control measures and mitigation efforts, were produced. The findings of the assessment showed 1 Moderate residual risk and 27 Low or Negligible residual risks. The one remaining Moderate risk, was associated with the risk of damage to infrastructure resulting from an increased frequency and severity of forest fires due to climate change.

SUMMARY OF FINDINGS

The findings of the assessment show that the Project is vulnerable to the effects of climate change and extreme weather events, including changes to temperature, precipitation, drought, and storm events. These results are documented in the Phase 1 report. These vulnerabilities result in material risks to the Project, including damage to infrastructure, water quality and availability impacts, disruption to operations and service delivery, and other impacts.

However, these risks are appropriately mitigated by the Project using control measures applied to the design or planned operations of the Project. As a result, based on the risks identified, the Project is considered to have a sufficient level of resilience to climate and weather-related risks.

It is recommended that the Project periodically revisit the vulnerability, risks and control measured considered in this assessment as new information becomes available, including climate projections, changes to operating parameters and local conditions.

3 INTRODUCTION

3.1 BACKGROUND

3.1.1 CLIMATE LENS ASSESSMENT

was commissioned by the Comox Valley Regional District (CVRD) to conduct a Climate Lens assessment for the Comox Valley Water Treatment Project (the Project). The Climate Lens was created by Infrastructure Canada to help address climate change impacts and GHG emissions of infrastructure projects in Canada. By incorporating climate considerations during the planning and design of infrastructure projects, the Climate Lens is intended to help assess the impact of projects, influence the design process, and inform funding decisions. This effort is an essential part of federal and regional governments' strategy to achieving Canada's 2030 GHG reduction target of 30% below 2005 levels, as documented in the Pan-Canadian Framework for Clean Growth and Climate Change[2].

British Columbia and Vancouver Island face unique threats caused by climate change. These threats include an increased frequency of extreme weather events and chronic effects caused by incremental changes in temperature and weather conditions. Given the longevity of infrastructure projects and the role they play in supporting communities with critical services, it is important that these projects are built with the future in mind.

The Climate Lens consists of two elements: a GHG Mitigation Assessment and a Climate Change Resilience Assessment. The GHG Mitigation Assessment and the Preliminary Climate Change Resilience Assessment (Phase 1) are contained in separate reports. This report provides the detailed assessment p hase (Phase 2) of the Climate Change
Resilience Assessment and is intended to be reviewed alongside the Phase 1 report.

3.1.2 PROJECT OVERVIEW

The Project is located near Courtenay, British Columbia and will draw water from Comox Lake. The Project consists of the construction of a new Comox Lake water intake, raw water pump station (RWPS), filtration water treatment plant (WTP) with direct filtration and UV disinfection, and additional buried conveyance piping. New components will integrate with existing infrastructure including downstream conveyance piping, as well as emergency back-up pumping station and chlorination facility. The Project may also re-use two UV disinfection reactors currently housed in the chlorination facility and will remove the existing water supply connection from a BC Hydro penstock.

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[2] Environment and Climate Change Canada. (2016). *Pan-Canadian Framework on Clean Growth and Climate Change* (pp. 1-78, Rep.). Gatineau, Quebec: Environment and Climate Change Canada. doi:http://publications.gc.ca/site/eng/9.828774/publication.html

CVRD commissioned the Project in response to a directive from the Vancouver Island Health Authority (Island Health) to provide filtration as part of their water treatment system. The region's existing water treatment consists of disinfection followed by chlorination treatment and does not provide filtration. In 2014 and 2015, Boil Water Notices (BWN) were issued in response to increased turbidity levels lasting a total of 57 days, prompting Island Health to direct CVRD to provide a water treatment facility which included filtration before September 30, 2019. Complying with this directive would bring CVRD into compliance with the British Columbia *Drinking Water Protection Act.* Additional BWN events have occurred in 2016 and 2017.

Refer to the Phase 1 Climate Change Resilience Report (17P-00108-00-00633) for a complete description of the project.

3.2 APPROACH

The Climate Change Resilience Assessment has been divided into two phases. Phase 1 of the assessment consists of a climate sensitivity analysis and climate exposure analysis, culminating in an assessment of climate vulnerability for the Project. The outcome of Phase 1 identified several Medium and High classification vulnerabilities and laid the groundwork for subsequent risk analysis in Phase 2.

This phased approach allowed the study to adjust the level of detail and focus of the risk analysis to the most relevant vulnerabilities and needs of the Project. This approach is consistent with the Climate Lens guidance, which suggests that a preliminary assessment phase may be appropriate to determine if more detailed analysis is required.

The Phase 2 assessment, the subject of this report, builds on the Phase 1 report and, combined, meets the requirements of the Climate Lens.

3.2.1 PHASE 1: PRELIMINARY RESILIENCE ASSESSMENT

The purpose of the Phase 1 assessment was to identify climate- and weather-related risks that the Project is likely to be vulnerable to. The steps undertaken in the assessment are illustrated in Figure 3-1 and described below.

Figure 3-1 Steps illustrating the preliminary resilience assessment process

The climate vulnerability assessment is informed by a climate sensitivity analysis and an assessment of climate exposure (both current and future). The sensitivity analysis focuses on identifying the sensitivities of the type of activities associated with the Project to extreme weather and climate change. As the focus is on the risks associated with weather and climate change, seismic activity and other environmental risks not caused by climate change have been excluded from this assessment. The sensitivity of the project elements has been determined in relation to a range of climate variables and climate-related hazards. A

sensitivity rating and exposure rating table are used to summarize the main sensitivities and exposure of the proposed project elements to climate- and weather-related risks.

The level of exposure of the project was determined based on historical weather data (where available) and an analysis of scenarios for projected future climate and literature review of climate hazards, taking into consideration the associated uncertainty. The vulnerability of project elements to climate- and weather-related impacts is then determined by using a simple matrix. High and Medium vulnerabilities are then taken forward to the detailed assessment stage (Phase 2).

In addition to the vulnerability assessment, Phase 1 provides the project description, defines boundaries for the assessment and provides the weather and climate data necessary to complete the Phase 2 assessment. The Phase 1 Climate Change Resilience Assessment report is intended to be read in conjunction with the Phase 2 report.

3.2.2 PHASE 2: DETAILED RESILIENCE ASSESSMENT

The purpose of the Phase 2 assessment contained in this report was to identify risks and opportunities associated with the identified climate- and weather-related risks and to develop mitigation and adaptation measures that may reduce these risks. Details about the steps to be undertaken are described below.

The detailed resilience assessment was grouped into the following stages:

- **Risk analysis** - in this stage, risks are identified and described based on the climate and weather effects and vulnerabilities assessed in the Phase 1 assessment. The output of this stage is an initial risk register.
- **Risk evaluation** – in this stage, the risks are compared and the likelihood and consequence of each risk are systematically rated. The risks are evaluated to determine their severity, with special attention given to unacceptable risks. The result of this stage is an initial risk rating for each risk and phase of the Project.
- **Risk mitigation** – in this stage, the effect of control measures on residual risk is investigated. An assessment is made of the feasibility, effectiveness and cost-benefits of each control or adaptation measure considered for unacceptable risks. These are compared with the status quo. The remaining (residual) risk is then rated and described. Possible adaptation measures are also identified to further mitigate risk.

The risk evaluation and mitigation process followed in this study is presented in Figure 3-2.

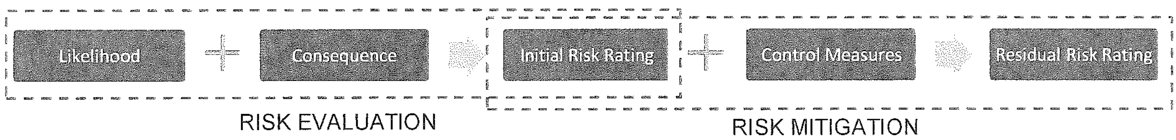

Figure 3-2 Steps illustrating the process followed in the Phase 2 assessment

3.2.3 PROJECT DOCUMENTS

The following Project information was consulted in undertaking the assessment:

- All documents reviewed during the Phase 1 assessment and described in the Phase 1 Preliminary Climate Change Resilience Report (17P-00108-00-00633)
- Puntledge River Fisheries Habitat Effects Assessment, EcoFish Research Limited, 2018
- Comox Lake Watershed Protection Plan, Aqua-Tex Scientific Consulting Ltd., 2016
- Climate Change Impacts on Hydrology for the Comox Lake Watershed, PCIP, 2018
- Comox Valley Water System Emergency Response Plan (Draft), CVRD, 2018
- BCEAO Project Description (Rev. 6) Comox Valley Water Treatment Project Appendix 2: Interactive Design Report, OPUS, 2017
- Water Systems Study, Koers and Associates Limited, 2013
- Comox Valley Regional Water Supply Strategy Technical Memorandum #5, Kerr Wood Leidal, 2010

4 PHASE 1: PRELIMINARY RESILIENCE ASSESSMENT (UPDATE)

4.1 INCORPORATION OF NEW FINDINGS

The Phase 1 assessment provided the groundwork for the Phase 2 assessment contained in this report, including the following elements:

- Project description – defining the project infrastructure, key parameters, lifecycle phases, and assessment boundaries and timelines
- Sensitivity analysis – defining and rating the climate variables relevant to water treatment plants and associated infrastructure
- Exposure analysis – defining and describing the current and projected climate and weather-related effects
- Vulnerability ratings – developing vulnerability ratings based on sensitivities and exposures for the construction and operation and maintenance phases of the Project.

Since the completion of the Phase 1 report, concurrent studies have been completed which have added important information to the assessment of current and projected climate and weather-related vulnerabilities in the Phase 1 assessment, and the analysis of risks and control measures in the Phase 2 assessment. These studies include:

- The Puntledge River Fisheries Habitat Effects Assessment (EcoFish, 2018)
- Climate Change Impacts on Hydrology for the Comox Lake Watershed Report (PCIP, 2018)

The EcoFish study provided additional relevant information for assessing the resilience of the Project, including:

- Control measures for maintaining Comox Lake and downstream water levels
- Projecting future water demands within the region
- BC Hydro operating procedures and operating ranges and thresholds for regulating Comox Lake water levels and downstream flow rates
- Evapotranspiration rates and their influence on Comox Lake water levels, which are expected to be negligible
- Impacts of climate change variables on fish species and populations.

Similarly, the PCIP study provided additional relevant information including:

- The contribution of glacial input into Comox Lake.

4.2 UPDATED VULNERABILITY RATINGS

The vulnerabilities resulting from the Phase 1 assessment were revisited based on the findings of the EcoFish and PCIP studies. This led to an adjustment of the vulnerability of glacier melt during the operation and maintenance phase of the project from a High to Low rating. The updated table of

Medium-rated vulnerabilities identified for the Project are presented in Table 4-1. Note that the updated Phase 1 assessment ratings resulted in no High-rated vulnerabilities.

Table 4-1 Updated Medium-rated Vulnerabilities for the Project

CONSTRUCTION PHASE	OPERATION & MAINTENANCE PHASE
— Extreme rainfall events — Extreme temperature events — Snow and ice — Gales and extreme wind events — Storms (snow, hail, dust and lightning)	— Extreme temperature events — Change in average rainfall — Drought — Extreme rainfall events (flooding) — Changes in source lake water levels — Snow and ice — Gales and extreme wind events — Storms (snow, hail, dust and lightning) — Change in annual average evaporation — Soil stability

4.3 UPDATES TO ASSESSMENT OF RISKS

The new information provided by the EcoFish and PCIP reports have been incorporated into the analysis and evaluation of risks in this report. These reports have affected the analysis of the following risks (a detailed description of each risk is provided in Appendix B and Section 5):

R15: Increased overland runoff from large precipitation events

- The conclusions of the Phase 1 assessment were consistent with the findings of the EcoFish report and improved the likelihood confidence rating by adding evidence of projected increases in winter and fall river flow rates.

R19: Increased temperatures leading to glacial retreat and risk of reduced inflow to Comox Lake

- Phase 1 initially concluded that the amount of inflow being provided from the glaciers surrounding Comox Lake was indeterminate and therefore glacial retreat could potentially have a significant impact on the water levels of the lake. The PCIP report clarified the input amount to be less than 3% and not a significant source of inflow into the lake, and therefore the likelihood of this risk was set to Low.

R20: Changes in stability of annual water availability due to retreating glaciers

- Phase 1 initially concluded that the amount of inflow being provided from the glaciers surrounding Comox Lake was indeterminate and therefore glacial retreat could potentially have a significant impact on the stability of annual water availability of the lake. The PCIP report clarified the input amount to be less than 3% and not a significant source of inflow into the lake. In addition, the EcoFish report noted that BC Hydro's control measures would stabilize the flow levels of the lake to within their desired parameters with a 95 percent confidence level. This new information was reflected in a Low residual risk rating.

R21: Low flows of in-take water owing to reduced summer rainfall

- The EcoFish report projected that under an RCP 8.5 climate change scenario (see Phase 1 report for definition) there will be no significant reduction in flow to fish territory. This information was reflected in the reduced consequence rating of this risk. In addition, the report provided information pertaining to the mitigation and control measures in place by BC Hydro and CVRD to control water levels, which was reflected in a Low residual risk rating assign to this risk.

R22: Low flows owing to increases in evapotranspiration rates

- The EcoFish report determined that the projected loses from evapotranspiration are insignificant and so the residual risk rating for this risk was reduced from Low to Negligible.

R25: Increased demand for water due to increasing temperatures and decreasing summer precipitation

- The EcoFish report determined that the impacts of increased population growth and potable water demand were not a significant risk after considering control measures. As a result, the residual risk rating assign to this risk was reduced from Low to Negligible.

5 PHASE 2: DETAILED RESILIENCE ASSESSMENT

5.1 OVERVIEW

This section describes the detailed climate resilience assessment. Climate and weather-related risks are identified based on the Medium and High-ranked vulnerabilities identified in the Phase 1 assessment. These risks are described in Section 5.2. The likelihood and consequence of each risk is rated and then combined to result in an initial risk rating presented in Section 0. The planned control measures identified by the Project are then evaluated to result in a final residual risk rating in Section 5.4. The remaining significant residual risks are discussed in Section 5.5 followed by a description of climate change related opportunities in Section 0.

5.2 RISK ANALYSIS

The Climate Lens Guidance[3] defines risk as "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity." Applying this definition, climate- and weather-related risks have been identified by reviewing the available project documentation and relevant literature (see Section 3.2.3) and by applying expert opinion and experience of previous similar projects. Table 5-1 presents a list of risks grouped into the following categories:

- Damage to Infrastructure
- Water Quality Impacts
- Water Availability Impacts
- Disruption to Operations and Service Delivery
- Miscellaneous

[3] Canada, Infrastructure Canada. (20118). *Climate Lens General Guidance* (Vol. 1.1, pp. 1-50). Infrastructure Canada.

Table 5-1 Description of Climate and Weather-related Risks

RISK CATEGORY: DAMAGE TO INFRASTRUCTURE

ID	RISK	DESCRIPTION
R1	Flooding of the Project from storm surges	During storm events coastal locations can experience abnormal rises in sea level caused primarily by storm winds uplifting water onshore. These storm surge events can cause extreme flooding in coastal areas and lead to expensive property damage, erosion of beaches (further reducing coastal protection) and coastal roads, injury and loss of life. Climate- and weather-related risks to the Project may include significant damage to physical infrastructure, injury or loss of life to employees, costly repairs, or inability to provide services.
R2	Flooding of the Project from extreme rainfall events (pluvial flooding)	Flooding can occur when areas become oversaturated due to extreme rainfall. Risks to the Project include significant property damage, injury, loss of life, costly repair and disruption of services.
R3	Damage to Project infrastructure from storm events	Intense storm events may consist of coastal storm surges, pluvial flooding, high winds, lightning, hail, or heavy snowfall. Risks to the Project include significant property damage, injury, loss of life, costly repairs and disruption of services.
R4	Increased fire risk to infrastructure owing to increased air temperatures, including increased risk of forest fire and equipment overheating	Increased temperatures in the absence of precipitation will lead to drier forest and vegetation conditions which increases the risk of forest fire. If temperatures increase in any location where mechanical equipment is stored and operated, this will increase the possibility of overheating and lead to mechanical fires. Both forest and equipment fires can pose significant risks to Project infrastructure, human life and the ability to provide services.
R5	Damage to foundations from desiccation of soils	Desiccation of soils is the process of extreme drying leading to instability. This is more likely to occur during conditions of increased temperature combined with decreased precipitation. Desiccated soils can cause subsidizing and shifting of foundations and can cause costly foundation damage, damage to the overall structure and human health and safety.
R6	High winds from storms leading to damage of Project structures	In addition to directly damaging buildings and infrastructure of the Project, high winds from storms can fell objects such as trees and cause them to damage Project infrastructure, block roadways (thereby reducing access) and/or injure employees and visitors.
R7	Changing water temperatures impacting the thermal expansion and contraction of the marine pipeline	High Density Polyethylene (HDPE) pipe (the specification of pipe planned for the construction of the marine pipeline) has a high coefficient of thermal expansion (the tendency of a matter to change shape, area, or volume in response to temperature). An unrestrained pipe will expand and contract its length with temperature changes, while a constrained pipe may be subject to internal stresses. If not accounted for, restrained pipe may apply stresses to restraining structures and cause damage which are costly to repair and that may result in disruption of service.
R8	Vegetation death reducing soil stability of the Project site	Temperature and precipitation fluctuations outside of normal ranges may cause premature vegetation death. Vegetation protects soil from the erosive processes of wind, provides stability through roots and help regulate water content (through slowing water movement). Vegetative death causes increased soil instability and erosion which can increase the risk foundation failure, damage to infrastructure and the health and safety of site users.

RISK CATEGORY: DAMAGE TO INFRASTRUCTURE

ID	RISK	DESCRIPTION
R9	Storm events disabling communication systems	Storm events, such as high winds and precipitation, may fell power lines or damage communications infrastructure, both within and outside of the Project boundary. Reduced (or damaged) communication systems may result in delayed or restricted access to emergency services for the health and safety of employees and staff and lack of ability of staff and equipment to coordinate for normal services
R10	Storm/flood conditions reducing access to Project infrastructure for staff, deliveries, or emergency services	Storms and flooding may block main transportation routes into and out of the Project by flooding or damaging the road, or debris causing blockage. This introduces a risk to employees entering and exiting the facility, delivery of supplies and emergency services access to the site.

RISK CATEGORY: WATER QUALITY IMPACTS

ID	RISK	DESCRIPTION
R11	Extreme rainfall events causing increased mobilization of sediments and pollutants	The force of heavy rainfall increases erosion of surface sediments and pollutants and increases their transport into waterways through overland flow. This increases the amount of sediments and pollutants in the water supply and alters the physical and chemical properties of the supplied water.
R12	Increased risk of blue-algal blooms (cyanobacteria) in Comox Lake owing to increased temperatures	Increased temperatures may increase the rate of growth of algal blooms. Algal blooms themselves increase water turbidity and dead and dying blooms can release toxins which may be harmful to human health and the health of the lake ecosystem. This may alter the chemical and biological composition of Comox Lake. It should be noted that only a small percentage of algal blooms produce harmful toxins, though they can be fatal to humans.
R13	Increase in water turbidity from increase in phytoplankton	Phytoplankton are microscopic marine plants which often compose the bottom of the aquatic food chain. Rising temperatures may increase the rate of growth of phytoplankton in Comox Lake which risks altering the physical and chemical composition of water, most notably increasing the turbidity which will have impacts on water quality.
R14	Increased water surface turbulence due to high winds	High winds can physically increase the turbulence of surface waters which in turn may increase the turbidity of the water in Comox Lake. This may affect water quality and operational costs.
R15	Increased overland runoff from large precipitation events	High precipitation events increase surface runoff which may increase the amount of sedimentation and pollutants carried into main waterbodies. This may alter the physical, chemical, and biological composition of the water and potentially reduce water quality and increase treatment costs.
R16	Increased risk of waterborne pathogens being driven into the water system due to increased precipitation intensities	High precipitation events increase surface runoff which may increase the volume of pathogens transported into waterbodies. As a result, new pathogens may be introduced into the water system which can decrease the water quality and impact the health and safety of the population as well the cost of operations.

RISK CATEGORY: WATER QUALITY IMPACTS

ID	RISK	DESCRIPTION
R17	Reduction of input water quality owing to fires, from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife.	Wildfires destroy local vegetation which exposes soil to higher erosion rates. This causes more sediment and surface pollutants to be carried into the water system through wind or overland runoff. This destruction of vegetation may also cause a change in the local hydrological cycle, which alters sediment and nutrient transfer into a water source. In addition, ash from fires as well as destroyed vegetation and animals may enter the waterway and introduce elevated concentrations of nutrients into receiving waterbodies. Fire retardants used to combat fires may also introduce new nutrients into the water system. This affects the physical, chemical, and biological composition of receiving waterbodies which poses a risk to the health and safety customers and presents an increased cost of treatment and operations.
R18	Decreased summer precipitation with increased evapotranspiration rates may reduce the capacity of surface water to dilute and remove pollutants and may change patterns of microbial growth and increase levels of biological contamination.	Decreased summer precipitation coupled with increased summer evapotranspiration rates may reduce the amount of water available to dilute terrestrial sediments and pollutants while they are being transported into waterways. This will lead to more concentrated inputs of sediments and pollutants being delivered into the water system which may affect the biological, physical, and chemical composition of the water and impact water quality, human health, and increase operational costs.

RISK CATEGORY: WATER AVAILABILITY IMPACTS

ID	RISK	DESCRIPTION
R19	Increased temperatures leading to glacial retreat and risk of reduced inflow to Comox Lake	Increasing average annual temperatures are causing an increase in the melting rate of the glacial systems in the Comox Lake watershed as well as a shift from snow to rain in the winter months which decreases their ability to be replenished. This causes glaciers to reduce in size and retreat. This will eventually eliminate glaciers as an input source for Comox Lake and may impact water availability.
R20	Changes in stability of annual water availability due to retreating glaciers	Glacier-fed or partially glacier-fed lakes rely on summer melting of ice to stabilize water levels in late spring and early summer. Without a glacial source the volume of water in the lake may increase in variability, affecting availability.
R21	Low flows of in-take water owing to reduced summer rainfall	A decrease in summer precipitation reduces a source of inflow into Comox Lake which may impact water levels and availability.
R22	Low flows owing to increases in evapotranspiration rates	Evapotranspiration is the process by which transpiration from plants and evaporation from soils transfers water from the land into the atmosphere. This may cause changes to the hydrological cycle and reduce the amount of water inputted into Comox Lake, altering water availability and level.

RISK CATEGORY: DISRUPTION TO OPERATIONS AND SERVICE DELIVERY

ID	RISK	DESCRIPTION
R23	Risk to ability to sustaining operations during major wildfire events owing to increased water demand	Comox Lake is a reservoir and source of fire flow water during major fire events. If too much water must be dedicated to fire operations there may be a risk of lack of water availability or resources for drinking water or flow equalization.
R24	Risk to operations in the event of a fire from forced staff evacuations	Short or long-term evacuation of staff may jeopardize the Project's ability to operate and/or deliver potable water.
R25	Increased demand for water due to increasing temperatures and decreasing summer precipitation	Demand for water historically increases in warmer and drier conditions. If temperatures increase and precipitation decreases, notably in the summer, there may be more of a demand for treated water from the Project from businesses, industry, and the general population.
R26	Storms leading to power outages	Storms including strong winds and precipitation events can, and historically have, caused power outages which may impact the Project's ability to operate, especially if the lack of power persists long term.

RISK CATEGORY: MISCELLANEOUS

ID	RISK	DESCRIPTION
R27	Changes in parameters such as water flow, temperature, air temperature and others reducing fish populations	Fish populations rely on steady water parameters including water temperature, air temperature, and water flow rate which is at risk of being altered under changing climate conditions. This may risk a reduction in fish stock.
R28	Extreme building temperature conditions (indoor)	Increasing temperature variability as well as a general warming trend may cause in-building temperatures of the Project to exceed comfortable or safe limits, affecting human health and comfort.

5.3 RISK EVALUATION

5.3.1 LIKELIHOOD EVALUATION

Likelihood is defined by the Climate Lens Guidance as "the chance of an event or an incident happening, whether defined, measured or determined objectively or subjectively". The likelihood of each risk occurring was determined by studying climate projection data for the relevant climactic variables and examining historic instances of events, as completed in the Phase 1 Preliminary Assessment Report. and applying professional judgement. An example of this process is provided in Table 5-2 for Climate Risk R17. This risk relates to wildfires which are a product of increasing temperatures and decreasing precipitation. Future projections were examined for those two climate variables in the exposure analysis stage of the Phase 1 preliminary resilience assessment and projected conditions were found to be likely to occur. In addition, historical records were consulted and it was found that the Project is in a summer-dry subzone which has previously experienced wildfires. This data, in combination with the physical location of the Project in a forested area indicated that the event was likely to occur at least once a decade which, according to the likelihood Matrix (Appendix A), results in a likelihood rating of 'High'. This process was repeated for all the identified risks and opportunities. The full list of likelihood ratings and rationales are provided in Appendix B.

Table 5-2 Sample Likelihood Evaluation – Climate Risk R17

ID	RISK	LIKELIHOOD RATIONALE	LIKELIHOOD RATING
R17	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife	The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfire have historically occurred (Aqua-Tex Scientific Consulting Ltd, 2016). Climate projections (see Phase 1 Preliminary Assessment Report) project a continued increased in summer temperatures combined with a slight decrease in summer precipitation; this may increase dry conditions favoured by wildfires. In addition, the Project is located in close proximity to forests which increases its exposure to forest fires. Furthermore, being in a fire-prone area puts the project at risk from ash contamination, changes in erosion rates due to destruction of stabilizing vegetation, decaying wildlife contaminating the water, and contamination from any retardant used by the region to combat wildfires. This combination of proximity to forests, historical instances of fires in the area, and projected climate conditions which increase the conditions favourable to fires give this risk a 'High' Likelihood Rating.	High

5.3.2 CONSEQUENCE EVALUATION

Consequence is defined by ISO 31000 Risk Management as follows: "A consequence is the outcome of an event and has an effect on objectives".[4] Consequence ratings were determined by reviewing the available project documentation and relevant literature (see Section 3.2.3) and by applying expert opinion and experience of previous similar projects. For each risk, consequences for the following eight themes were considered:

- **Infrastructure**: the amount of loss or damage of physical infrastructure from no structural damage to a complete shutdown of the asset
- **Health and Safety (H&S):** the injury, disability, or loss of life of any person(s)
- **Governance**: the changes to government or policy required as a result of an action/event
- **Financial**: the monetary loses associated with compensating for an action/event
- **Social:** the impact on society and the Project's social license to operate – the overall acceptance of the Project by local communities and stakeholders
- **Environment:** the adverse effect on the environment
- **Economy:** the effect on the local and broader economy
- **Reputation:** the impact of an action/event on public opinion locally and nationally

Consequence ratings for each of these themes was applied using the consequence matrix found in Appendix A. An overall consequence rating was determined as appropriate using expert judgement by taking into account the relative consequence theme ratings and project information. The consequence ratings were determined independently of likelihood ratings. For example, an event with a Very Low likelihood could still have a Very High consequence rating, such as Climate Risk R1.: Flooding of WTP from storm surge. The likelihood for this risk was determined to be Very Low due to the geographical distance and elevation of the plant from the coast, however the consequence was determined to be High because of the potential infrastructure, health and safety, and financial effects on the Project.
Table 5-3 shows an example of the process of establishing a consequence rating for Climate Risk R17. This process was repeated for all of the identified risks and opportunities. The full list of consequence ratings and rationales can be found in Appendix B.

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[4] International Organization for Standardization. (2018). *Risk Management-Guideline.* (ISO/TC 262). Retrieved from https://www.iso.org/standard/65694.html

Table 5-3 Sample Consequence Evaluation – Climate Risk R17

ID	RISK	CONSEQUENCE RATIONALE	CONSEQUENCE RATINGS	
R17	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife	Fires can cause increased erosion and sediment rates, changes to hydrological structures due to vegetation destruction changing the magnitude and frequency of flooding events and overland flow transporting sediments, introduction of ash and fire retardant into the water system, and introduction of excess nutrients from fire retardant and animals' deaths. This may lead to an increase in bacterial loading, water turbidity, changes in nutrient content and changes in the amount of water input into the lake. This may put an excess strain on treatment infrastructure, pose an increased risk to human health through contaminated water, increase the cost of filtration, destroy local habitats, reduce local tourism and fishing capabilities, require a change in government policy, reduce logging stock, and cause social and reputational harm through the destruction of landscapes and reduction in the availability to provide clean water.	Infrastructure	Medium
			H&S	High
			Governance	Low
			Financial	Medium
			Social	Low
			Environment	V. High
			Economy	High
			Reputation	Low
			Combined Rating	**High**

5.3.3 *INITIAL RISK RATING RESULTS*

Risk is the product of likelihood and consequence. For the purposes of this report, the initial risk rating is defined as "the Risk before the consideration of mitigation efforts". As such, this is the climate- and weather-related that exists risk before any types of resilience or mitigative measures are considered and, while necessary in determining a residual risk rating, should not be considered as the final determinant risk rating.

The initial risk rating was calculated by comparing the product of the likelihood and the consequence ratings using the risk rating matrix (Appendix A). Initial risk ratings were developed for the construction and operation and maintenance phases of the Project. The operation and maintenance phase of the project considered 2050s and 2080s time periods to reflect the changing nature of climate risks over time. Table 5-4 shows the results of the risk evaluation stage, including the initial risk ratings for all risks identified during the assessment. The full results including confidence levels and rationales for likelihood and consequence ratings can be found in Appendix B.

Table 5-4 Initial Risk Rating Results

RISK CATEGORY: DAMAGE TO INFRASTRUCTURE

ID	RISK	LIKELIHOOD	CONSEQUENCE	INITIAL RISK RATING CONSTRUCTION	INITIAL RISK RATING 2050'S	INITIAL RISK RATING 2080'S
R1	Flooding of the Project from storm surges	Very Low	High	Low	Low	Low
R2	Flooding of the Project from extreme rainfall events (pluvial flooding)	Moderate	High	Moderate	High	High
R3	Damage to Project infrastructure from storm events	Low	High	Low	Moderate	Moderate
R4	Increased fire risk to infrastructure from increased temperature including increased risk of forest fire and equipment overheating	High	High	Moderate	High	High
R5	Damage to foundation from desiccation of soils	Low	High	Negligible	Moderate	Moderate
R6	High winds from storms leading to damage of Project structures	Low	Moderate	Low	Low	Low
R7	Changing water temperatures impacting the thermal expansion and contraction of the marine pipeline	Very Low	Moderate		Low	Low
R8	Vegetation death reducing soil stability of the Project site	Low	Moderate		Low	Low
R9	Storm events disabling Project communications	Moderate	Moderate	Low	Moderate	Moderate
R10	Storm/flood conditions reducing access to project infrastructure for staff, deliveries, or emergency services.	Moderate	Moderate	Moderate	Moderate	Moderate

RISK CATEGORY: WATER QUALITY IMPACTS

ID	RISK	LIKELIHOOD	CONSEQUENCE	INITIAL RISK RATING CONSTRUCTION	INITIAL RISK RATING 2050'S	INITIAL RISK RATING 2080'S
R11	Extreme rainfall events cause increased mobilization of sediments and pollutants	High	Low		Moderate	Moderate
R12	Increased risk of blue-algal blooms (cyanobacteria) in Comox Lake, owing to increased temperatures	Moderate	Moderate		Moderate	Moderate
R13	Increase in water turbidity from increase in phytoplankton	Very Low	Low		Negligible	Negligible
R14	Increased water surface turbulence due to high winds	Low	Low		Low	Low
R15	Increased overland runoff from large precipitation events	High	Low		Moderate	Moderate

RISK CATEGORY: WATER QUALITY IMPACTS

ID	RISK	LIKELIHOOD	CONSEQUENCE	INITIAL RISK RATING CONSTRUCTION	2050'S	2080'S
R16	Increased risk of waterborne pathogens being driven into the water system due to increased precipitation intensities	Low	High		Moderate	Moderate
R17	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife.	High	High		High	High
R18	Decreased summer precipitation with increased evapotranspiration rates may reduce the capacity of surface water to dilute and remove pollutants and may change patterns of microbial growth and increase levels of biological contamination.	Moderate	Low		Low	Low

RISK CATEGORY: WATER AVAILABILITY IMPACTS

ID	RISK	LIKELIHOOD	CONSEQUENCE	INITIAL RISK RATING CONSTRUCTION	2050'S	2080'S
R19	Increased temperatures leading to glacial retreat and risk of reduced inflow to Comox Lake	Low	Low		Low	Low
R20	Changes in stability of annual water availability due to retreating glaciers	High	Low		Moderate	Moderate
R21	Low flows of in-take water owing to reduced summer rainfall	High	Moderate		High	High
R22	Low flows owing to increases in evapotranspiration rates	Very Low	Low		Negligible	Negligible

RISK CATEGORY: DISRUPTION TO OPERATIONS AND SERVICE DELIVERY

ID	RISK	LIKELIHOOD	CONSEQUENCE	INITIAL RISK RATING CONSTRUCTION	2050'S	2080'S
R23	Risk to ability to sustain operation during major wildfire events owing to increased water demand	Moderate	High		Low	Low
R24	Risk to operations in the event of a fire from forced staff evacuations	High	Moderate		Moderate	Moderate
R25	Increased demand for water due to increasing temperatures and decreasing summer precipitation	Moderate	Moderate		Moderate	Moderate
R26	Storms leading to power outages	High	Moderate	Moderate	High	High

RISK CATEGORY:	MISCELLANEOUS			INITIAL RISK RATING		
ID	RISK	LIKELIHOOD	CONSEQUENCE	CONSTRUCTION	2050'S	2080'S
R27	Changes in parameters such as water flow, temperature, air temperature and others reducing fish populations	Moderate	Moderate		Moderate	Moderate
R28	Extreme building temperature conditions (indoor)	High	Moderate		Moderate	High

5.4 RISK MITIGATION

5.4.1 CONTROL MEASURES AND ADEQUACY RATINGS

Control measures exist to increase the resilience of a project to different risks, including those related to climate and weather. Examples of control measures can include hard measures, such as control systems, sensors or barriers, and/or soft measures, such as risk assessment frameworks, strategies, and/or plans. The implementation and consideration of control measures and mitigation efforts increases the resilience of the Project and reduces its risk.

For the purpose of this assessment, mitigation efforts were considered in the context of planned control measures. Control measures were identified by reviewing the available project documentation and relevant literature (see Section 3.2.3) and by applying expert opinion and experience of previous similar projects.

The purpose of identifying these control measures was to determine if they reduced the initial risk ratings and to demonstrate the climate and weather-related resilience of the Project. Each control measure was given one of the following adequacy ratings to determine their effectiveness in mitigating risk:

- **N/A:** Control measures were deemed unnecessary or not applicable, typically applied to lower initial risk ratings
- **Inadequate:** The control measures were deemed insufficient to mitigate climate risks
- **Adequate:** The control measures were deemed sufficient to mitigate climate risks
- **Optimal:** The control measures were ideal for mitigating climate risks
- **Excessive:** The control measures went above what is necessary to mitigate climate risks

Adequacy ratings were determined for each identified risk. During this stage, the Project engineers and owners and subject matter experts were engaged.

Table 5-5 provides an example of the process of considering and applying control measures to identified risks. The example uses Climate Risk R17, which includes the following control measures: building to regulation fire standards, incorporating alarm systems, ensuring sufficient water availability, installing fire hydrants and through ensuring sufficient clearance for emergency vehicles on roads. In this example, an 'Adequate' rating was applied to the control measures.

Table 5-5 Sample Control Measure Evaluation – Climate Risk R17

CATEGORY	DESCRIPTION
RISK ID	R17
RISK	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife.
CONTROL MEASURES	The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment. The main loop and secondary roads will be able to accommodate fire trucks (OPUS. 2017). The Comox Valley Water Treatment Project is subject to the codes and standards of the Fire Underwriter's Survey, The National Fire Code of Canada 2012, The British Columbia Building Code, and the National Fire Protection Association. The facilities will have fire flows provided by a domestic water pumping supply system from the clearwell. The RWPS and WTP will have a fire flow of a minimum of 150L/s with sprinklers. Hydrant placement on roads will comply with the MMCD Design Guidelines as well as the 2012 British Columbia Building Code, in addition to a fire alarm system with horns, lights, and smoke detectors (OPUS, 2017). As the watershed is the site of various logging and recreational activities there are several methods in place to reduce the risks of fire including: forestry and logging companies perform routine fire patrols have response plans in place, often above minimum standards, fire cutblocks may be used to limit spread, forest companies implement forest closures based on local conditions, campfires are not permitted within Strathcona national park, public access is restricted during times of high fire risk by fire wardens and staff (public and private), forestry operations are shut down when fire risk is high, forestry companies in the area have their own fire suppression equipment on site, and the area is large enough to allow for aerial suppression (Aqua-Tex Scientific Consulting Ltd, 2016). In addition, the Comox Valley Lake Watershed protection plan has recommended the following actions: introducing fire suppression into the emergency management plan, better integration of fire management through the various parties in the watershed (private vs public entities), and reducing the unnecessary use of fire retardants (Aqua-Tex Scientific Consulting Ltd, 2016).
ADEQUACY RATIONALE	The project has included or documented what we consider to be most reasonable control measures to reduce the risk of fire including abiding by regulatory standards, use of mechanical systems to mitigate fire risk, built-in system redundancy and means to control the severity of the risk (lowered water quality).
ADEQUACY RATING	Adequate

The Climate Lens Guidance notes that adequacy ratings could also consider the cost of each control measure with regards to the Return on Investment (ROI) and/or resilience benefit (e.g. cost avoided) each measure may be expected to provide. In this assessment, ROI and the avoided costs from control measures were not considered as the existing measures already incorporated into the Project design and operating plan are adequate, resulting in a relatively low and acceptable level of residual risk (see Section 5.4.3 and Section 6).

5.4.2 EVALUATION OF RESIDUAL RISK

The Climate Lens Guidance defines residual risk as “the risk that is left over after risk mitigation efforts.” This is the final risk of the Project to climate change and weather-related impacts. Residual risk was determined by considering the initial risk rating and the adequacy of the control measures considered for each risk. For example, Climate Risk R26 (storms leading to power outages), was determined to have an initial risk rating of High. Control measures identified included a resilient backup power system of two waterproof, vandal-proof diesel fuel powered generators which could ensure a backup supply of 24 hours of power. These control measure reduced the Residual Risk Rating to a Low. Table 5-6 illustrates the relationship between initial and residual risk ratings for Climate Risk R17.

Table 5-6 Sample Residual Risk Rating – Climate Risk R17

	INITIAL RISK RATING			ADEQUACY RATING	RESIDUAL RISK RATING		
ID	CONSTRUCTION	2050'S	2080'S		CONSTRUCTION	2050'S	2080'S
R17	High	High	High	Adequate	Low	Low	Low

5.4.3 RESIDUAL RISK RATING RESULTS

The final residual risk ratings for all climate and weather-related risks identified in this assessment are presented in Table 5-7. The results show that nearly all risks have been reduced to an acceptable, Negligible or Low rating due to the control measures already incorporated into the design and planned operation of the Project. Only Climate Risk R4 has a Moderate residual risk rating after applying appropriate control measures. This risk was the focus of additional analysis and is discussed in greater detail in Section 5.5.

Table 5-7 Residual Risk Rating Results

ID	RISK CATEGORY: DAMAGE TO INFRASTRUCTURE RISK	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING CONSTRUCTION	2050'S	2080'S
R1	Flooding of the Project from storm surges	Low	Optimal	Negligible	Negligible	Negligible
R2	Flooding of the Project from extreme rainfall events (pluvial flooding)	High	Optimal	Low	Low	Low
R3	Damage to Project infrastructure from storm events	Moderate	Optimal	Low	Low	Low
R4	Increased fire risk to infrastructure from increased temperature including increased risk of forest fire and equipment overheating	High	Adequate	Low	Moderate	Moderate
R5	Damage to foundation from desiccation of soils	Moderate	Adequate	Negligible	Low	Low
R6	High winds from storms leading to damage of Project structures	Low	Adequate	Low	Low	Low
R7	Changing water temperatures impacting the thermal expansion and contraction of the marine pipeline	Low	Adequate		Negligible	Negligible
R8	Vegetation death reducing soil stability of the Project site	Low	Adequate		Negligible	Negligible
R9	Storm events disabling Project communications	Moderate	Adequate	Low	Low	Low
R10	Storm/flood conditions reducing access to project infrastructure for staff, deliveries, or emergency services.	Moderate	Adequate	Low	Low	Low

ID	RISK CATEGORY: WATER QUALITY IMPACTS RISK	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING CONSTRUCTION	2050'S	2080'S
R11	Extreme rainfall events cause increased mobilization of sediments and pollutants	Moderate	Optimal		Negligible	Negligible
R12	Increased risk of blue-algal blooms (cyanobacteria) in Comox Lake, owing to increased temperatures	Moderate	Optimal		Negligible	Negligible
R13	Increase in water turbidity from increase in phytoplankton	Negligible	Adequate		Negligible	Negligible
R14	Increased water surface turbulence due to high winds	Low	Adequate		Negligible	Negligible
R15	Increased overland runoff from large precipitation events	Moderate	Adequate		Negligible	Negligible

RISK CATEGORY: WATER QUALITY IMPACTS

ID	RISK	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING: CONSTRUCTION	RESIDUAL RISK RATING: 2050'S	RESIDUAL RISK RATING: 2080'S
R16	Increased risk of waterborne pathogens being driven into the water system due to increased precipitation intensities	Moderate	Adequate		Low	Low
R17	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife.	High	Adequate		Low	Low
R18	Decreased summer precipitation with increased evapotranspiration rates may reduce the capacity of surface water to dilute and remove pollutants and may change patterns of microbial growth and increase levels of biological contamination.	Low	Adequate		Negligible	Negligible

RISK CATEGORY: WATER AVAILABILITY IMPACTS

ID	RISK	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING: CONSTRUCTION	RESIDUAL RISK RATING: 2050'S	RESIDUAL RISK RATING: 2080'S
R19	Increased temperatures leading to glacial retreat and risk of reduced inflow to Comox Lake	Low	Adequate		Low	Low
R20	Changes in stability of annual water availability due to retreating glaciers	Moderate	Adequate		Low	Low
R21	Low flows of in-take water owing to reduced summer rainfall	High	Adequate		Low	Low
R22	Low flows owing to increases in evapotranspiration rates	Negligible	Adequate		Negligible	Negligible

RISK CATEGORY: DISRUPTION TO OPERATIONS AND SERVICES

ID	RISK	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING: CONSTRUCTION	RESIDUAL RISK RATING: 2050'S	RESIDUAL RISK RATING: 2080'S
R23	Risk to ability to sustain operation during major wildfire events owing to increased water demand	Low	Adequate		Low	Low
R24	Risk to operations in the event of a fire from forced staff evacuations	Moderate	Adequate		Low	Low
R25	Increased demand for water due to increasing temperatures and decreasing summer precipitation	Moderate	Adequate		Negligible	Negligible
R26	Storms leading to power outages	High	Adequate	Negligible	Low	Low

RISK CATEGORY:	MISCELLANEOUS	MAXIMUM INITIAL RISK RATING	CONTROL MEASURE ADEQUACY	RESIDUAL RISK RATING		
ID	RISK			CONSTRUCTION	2050'S	2080'S
R27	Changes in parameters such as water flow, temperature, air temperature and others reducing fish populations	Moderate	Adequate		Low	Low
R28	Extreme building temperature conditions (indoor)	[redacted]	Adequate		Low	Low

5.4.4 ADAPTATION RESPONSES AND MONITORING PLANS

Adaptation responses are necessary to identify what action is required following the assessment of risks. These responses may be defined as:

- **N/A:** Not applicable or not available
- **Watching brief:** the risk is anticipated to emerge in the long-term and therefore an ongoing watching brief should be undertaken of the science and effects of climate change
- **Sustain current action:** current controls are sufficient to manage the risk. Existing measures and risks should be regularly monitored
- **Research priority:** additional research is needed and/or development prior to confirming any risk management actions
- **More action needed**: action is required in the short-term, either to manage short-term risks or because the solution to longer-term risks needs to start now because of long-term planning or implementation cycles

The required adaptation response was determined based on the presence of existing control measures, the assessment of adequacy, and using expert judgement. This analysis was applied to Climate Risk R4, the only moderate residual risk resulting from the assessment, as well as selected lower risks where an adaptation response would be beneficial.

A 'watching brief' adaptation response was selected for Climate Risk R4 and other risks where the risk is anticipated to emerge over the long-term and therefore an ongoing watching brief should be undertaken of the science and effects of climate change to better understand its future impacts. A monitoring plan is necessary to periodically review these risks in light of the availability of new climate data, additional (or better) control measures, or other factors that may affect the initial or residual risk ratings. Table 5-8 describes a monitoring plan, including data that may need to be collected and the frequency of collection, for each of the watching briefs identified.

Table 5-8 Monitoring Plans for Risks with Watching Briefs

ID	RISK	DATA REQUIRED / COLLECTION METHOD	MONITORING FREQUENCY	SUCCESS CRITERIA	MEASUREMENT
R4	Increased fire risk to infrastructure from extreme temperatures and reduced summer precipitation including risks to equipment overheating	Instances of fire between now and 2050, improved climate projections, improved fire safety and defense techniques	Every 2-5 years	Reduction in reported fire risk	Count of recorded fire incidences per year
R3	Damage to infrastructure from wind and storms	New climate projections and history of storms and damage to buildings between construction and 2050	Every 2-5 years	No infrastructure damage and little to no change to service	Damage reports per year

ID	RISK	DATA REQUIRED / COLLECTION METHOD	MONITORING FREQUENCY	SUCCESS CRITERIA	MEASUREMENT
R10	Storm/flood conditions reducing access to project infrastructure for staff, deliveries, or emergency services.	Challenges in road access and monitoring of flooding	Every 2-5 years	No disruption to services and no injury or medical attention required	Incidences per year
R28	Extreme building temperature conditions (indoor)	Outdoor and indoor temperatures, technological advancements in HVAC systems	Every year	No injury or medical attention required	Incidences per year

5.5 CONSIDERATION OF REMAINING RESIDUAL RISKS

After considering planned control measures for the Project, all Moderate and High-rated initial risks were downgraded to Negligible to Low-rated residual risks except for Climate Risk R4. Despite adequate control measures, Climate Risk R4 has a moderate residual risk over longer time horizons resulting from increased forest fire risks due to climate change effects. Table 5-9 presents the risk analysis, evaluation and mitigation assessment stages for this risk. Additional information is available in Appendix B.

Table 5-9 Risk Assessment Process and Results for Moderate Residual Risks – Climate Risk R4

CATEGORY	DESCRIPTION
RISK ID	R4
RISK	Increased fire risk to infrastructure owing to increased air temperatures, including risk of forest fire and equipment overheating
LIKELIHOOD	**High -** The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfire have historically occurred (Aqua-Tex Scientific Consulting Ltd, 2016). Climate projections from the Phase 1 Preliminary Assessment Report show a continued increased in summer temperatures combined with a slight decrease in summer precipitation, which may increase conditions favorable to wildfires. The Project is also in a location surrounded by forests, which increases the exposure.
CONSEQUENCE	**High -** Fire poses a direct threat, principally, to staff and infrastructure. Wildfires increase the amounts of dissolved materials and turbidity in drinking water, in addition to increasing erosion. If fire retardant materials are used it may also increase traces of phosphate, nitrate, and nitrite in the water above acceptable standards. Electrical fires in the facilities can cause damage to infrastructure and equipment as well as pose a danger to human lives and safety. Fire repairs can be disruptive to operations and costly.
INITIAL RISK RATING	**Moderate** – Construction **High** - 2050s; 2080s

CATEGORY	DESCRIPTION
CONTROL MEASURES	The Comox Valley Water Treatment Project is subject to the codes and standards of the Fire Underwriter's Survey, The National Fire Code of Canada 2012, The British Columbia Building Code, and the National Fire Protection Association. The facilities will have fireflows provided by a domestic water pumping supply system from the clearwell. The RWPS and WTP will have a fire flow of a minimum of 150L/s with sprinklers. Hydrant placement on roads will comply with the MMCD Design Guidelines as well as the 2012 British Columbia Building Code, in addition to a fire alarm system with horns, lights, and smoke detectors. The building will also contain such fire protection elements such as a site fire pump, fire department connections, fire extinguishers, and water supplies from hydrants. The roofs, floors, and load bearing walls will have a fire resistance rating of no less than one hour. (OPUS, 2017) As the watershed is the site of various logging and recreational activities there are several methods in place to reduce the risks of fire including: forestry and logging companies perform routine fire patrols, have response plans in place, often above minimum standards, fire cutblocks may be used to limit spread, forest companies implement forest closures based on local conditions, campfires are not permitted within Strathcona national park, public access is restricted during times of high fire risk by fire wardens and staff (public and private), forestry operations are shut down when fire risk is high, forestry companies in the area have their own fire suppression equipment on site, and the area is large enough to allow for aerial suppression (Aqua-Tex Scientific Consulting Ltd, 2016).
ADEQUACY RATIONALE	The project has included or documented what we consider to be reasonable control measures to reduce the risk of fire, including abiding by regulatory standards, use of fire response systems, and preventative measures including forest management to control the likelihood and severity of the risk.
ADEQUACY RATING	Adequate
RESIDUAL RISK RATIONALE	The control measures provide a proportionate response to the risk. However, due to the increased prevalence of forest fires resulting from climate change impacts and the close proximity of the Project infrastructure to forested areas, there remains a moderate residual risk at longer time horizons.
RESIDUAL RISK RATING	**Low** – Construction **Moderate** - 2050s; 2080s

5.6 OPPORTUNITIES

Climate change-related opportunities were considered in parallel with the analysis and evaluation of risks in Section 5.2 and 0, respectively. The opportunities identified are described and rated in Table 5-10 and Table 5-11, respectively. Two opportunities were identified related to projected warming of average and seasonal temperatures. In each case, the opportunities were assigned Low ratings.

Table 5-10 Description of Climate-related Opportunities

ID	OPPORTUNITY
O1	Extra heat available through warmer temperatures may introduce an opportunity to improve some aspects of treatment (i.e. coagulation and settlement processes) and lead to increased removal efficiencies and reduced treatment costs.
O2	Increased winter temperatures may increase the opportunity to reduce complications due to freezing such as service disruptions from frozen infrastructure (i.e. pipes).

Table 5-11 Opportunity Rating Results

			OPPORTUNITY RATING		
ID	LIKELIHOOD	CONSEQUENCE	CONSTRUCTION	2050'S	2080'S
O1	Moderate	Low		Low	Low
O2	Moderate	Low		Low	Low

6 CONCLUSIONS

The Climate Change Resilience Assessment contained in the Phase 1 and Phase 2 reports have been conducted in accordance to the methods and requirements outlined by the Climate Lens. Combined, the assessment applied the best available climate data and projections and historical weather data to assess the vulnerabilities of the Project to changes in climate and extreme weather for the construction and operation and maintenance life of the assets. Risks were identified and evaluated based on likelihood and consequence resulting in an initial risk rating which contained 18 Moderate and High risks to the Project, especially over longer-term time horizons near 2050 and beyond. These risks, if not mitigated by the Project, could lead to damage to infrastructure, water quality and availability impacts, disruption to operations and service delivery, and other impacts.

Control measures already incorporated into the design or planned operations of the Project were identified and their effectiveness at mitigating each risk was evaluated. All control measures included in this investigation were assessed as Adequate to Optimal at mitigating the risks identified during the assessment. Residual risk ratings were assigned based on the effectiveness of the control measures, resulting in all risks receiving a Negligible to Low final rating except for one risk, which was Moderate. The remaining Moderate risk was associated with the risk of damage to infrastructure resulting from an increased frequency and severity of forest fires due to climate change. While adequately addressed by several control measures, it is difficult to completely remove the risks that such occurrences could have on critical infrastructure located in forested areas.

Based on the risks identified, the Project is considered to have a sufficient level of resilience to climate and weather-related risks. It is recommended that the Project periodically revisit the vulnerability, risks and control measured considered in this assessment as new information becomes available, including climate projections, changes to operating parameters and local conditions.

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A RATING MATRICES

A-1 VULNERABILITY TABLES

SENSITIVITY MATRIX EXAMPLE

Phase	Variable	Type	Project element(s)	
			WTPs	Sewerage networks
Construction	Temperature	Mean monthly temperature	Low	N/A
		Extreme temperature events	Medium	
	Precipitation	Mean monthly precipitation	Medium	Low
		Extreme precipitation events	High	High
		Drought	High	Medium
	Etc.	etc	etc	etc

Repeat for operation and maintenance
High sensitivity (red): Climate variable/hazard may have a significant impact;
Medium sensitivity (orange): Climate variable/hazard may have a slight impact;
Low sensitivity (green): Climate variable/hazard has little effect; and
N/A (white): Climate variable/hazard screened out.

EXPOSURE MATRIX EXAMPLE

Phase	Variable	Type	Project element(s)	
			WTPs	Sewerage networks
Construction	Temperature	Mean monthly temperature	Low	
		Extreme temperature events	Medium	
	Precipitation	Mean monthly precipitation	Medium	
		Extreme precipitation events	High	
		Drought	High	
	Etc.	etc	etc	

Repeat for Operation and Maintenance phases.
High exposure (red): Climate variable inflicts significant exposure;
Medium exposure (orange): Climate variable inflicts some exposure, and
Low exposure (green): Climate variable inflicts little or no exposure.

VULNERABILITY RATING MATRIX EXAMPLE

Sensitivity	Exposure		
	Low	Medium	High
Low	Low	Low	Low
Medium	Low	Medium	Medium
High	Low	Medium	High

A-2 RISK TABLES

ESTIMATES OF LIKELIHOOD OF RISKS

Probability range **Type of event**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Significant single event; or	Not likely to occur in period	Likely to occur once between 30 and 50 years	Likely to occur once between 10 and 30 years	Likely to occur at least once a decade	Likely to occur once or more annually
Ongoing/ Cumulative occurrence	Not likely to become critical/ beneficial in period	Likely to become critical/ beneficial in 30-50 years	Likely to become critical/ beneficial in 10-30 years	Likely to become critical/ beneficial in a decade	Will become critical/ beneficial in several years

ESTIMATES OF CONSEQUENCES OF RISK

Factor / Degree	Infrastructure	H&S	Governance	Financial	Social	Environmental	Economy	Reputation
Very Low	No infrastructure damage, little change to service. Impact can be absorbed through normal activity	First aid	No changes to management required	Little financial loss or increase in operating expenses	No impact on society	No adverse effects on natural environment. Localised to point source. No recovery required	No effect on the broader economy	Localised temporary impact on public opinion
Low	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. An adverse event which can be absorbed through business continuity actions	Minor injury, medical treatment with/or restricted work	General concern raised by regulators requiring response action	Additional operational costs. Financial loss small, <10% of turnover	Localised, temporary social impacts	Minimal effects on the natural environment. Localised within site boundaries. Recovery measurable within 1 month of impact	Minor effect on the broader economy due to disruption of service provided by the asset	Localised, short term impact on public opinion
Moderate	Limited infrastructure damage and loss of service, Damage recoverable by maintenance and minor repair. A serious event which requires additional emergency business continuity actions	Serious injury or lost work	Investigation by regulators Changes to management actions required	Moderate financial loss, 10-50% of turnover	Localised, long term social impacts	Some damage to the environment including local ecosystems. Some remedial action may be required. Recovery in 1 year.	High impact on the local economy with the some effect on the wider economy.	Local, long term impact on public opinion with adverse local media coverage
High	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service. A critical event which requires extraordinary/ emergency business continuity actions	Major or multiple injuries, permanent injury or disability	Notices issued by regulators for corrective actions. Changes required in management. Senior management responsibility questionable.	Major financial loss, 50-90% of turnover	Failure to protect poor or vulnerable groups. National, long term social impacts.	Significant effect on the environment and local ecosystems. Remedial action likely to be required. Recovery longer than 1 year. Failure to comply with environmental regulations / consents.	Serious effect on the local economy spreading to the wider economy	National, short term impact on public opinion; negative national media coverage
Very High	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure of the service. Loss of infrastructure support and translocation of service to other sites. Disaster with potential to lead to shut down or collapse of the asset / network	Single or multiple fatalities	Major policy shifts. Change to legislative requirements. Full change of management control	Extreme financial loss >90% of turnover	Loss of social license to operate. Community protests	Very significant loss to the environment. May include localised loss of species, habitats or ecosystems. Extensive remedial action essential to prevent further degradation. Restoration likely to be required. Recovery longer than 1 year. Limited prospect of full recovery.	Major effect on the local, regional and state economies	National, long term impact with potential to affect stability of Government

RISK RATING MATRIX

Consequence	Likelihood				
	Very Low	Low	Moderate	High	Very High
Very Low	Negligible	Negligible	Low	Low	Moderate
Low	Negligible	Low	Low	Moderate	High
Moderate	Low	Low	Moderate	High	High
High	Low	Moderate	High	High	Extreme
Very High	Moderate	High	High	Extreme	Extreme

Extreme Risk: Immediate controls required
High Risk: High priority control measures required
Moderate Risk: Some controls required to reduce risks to lower levels
Low Risk: Controls likely not required
Negligible Risk: Risk events do not require further consideration

B RISK REGISTER TABLES

RISK ANALYSIS TABLE – LEGEND

Type of event	Confidence	Ratings
(S)ingle (C)umulative	(L)ow (M)edium (H)igh	(VL) Very Low / (N) Negligible (L) Low (M) Moderate (H) High (VH) Very High

RISK ANALYSIS TABLE – DAMAGE TO INFRASTRUCTURE

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (If/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R1	Flooding of the Project from storm surges	Sea	All	N/A	S	M	The plant is located at sufficient distance from the coast (approximately 9.5km) and at a high enough elevation (approximately 150m asl) for this to not be a significant concern (OPUS, 2017).	VL	Flooding may cause extensive and costly infrastructure damage and pose a threat of injury or death to operation personnel and visitors to the WTP. The cost of fixing damages and the potential disruption to services during this time may involve a major financial commitment and a minor effect on the broader community.	H	H		H			L		H		L		**WTP:** A stormwater pond is required to attenuate a 1:100 year storm event, with an estimated drain time of less than 40 hours. Stormwater retention measures may include previous catch basins, infiltration trenches, infiltration basin, reduced lot grading. The location of the WTP site, near the Puntledge River, is situated at an elevation of between 132m and 142m which is above the historical flood elevation of the River. **RWPS:** The access elevation into the RWPS will be situated at an elevation of 139.9 m which is at the Probably Maximum Flood elevation (139.9m geodetic elevation) of Comox Lake. In addition, The electrical room and related electrical services (BC Hydro transformer and emergency generator) will be at an elevation of 142.9m, well above the Probably Maximum Flood elevation. As Comox Lake is a reservoir lake owned and operated by BC Hydro, when the water level gets too high BC Hydro systematically increases the water released from the reservoir to avoid spillage and flooding of the lake. The reservoir will begin to free-spill over the dam at approximately 135.33m asl, however BC Hydro prefers to keep it below 134.4m asl. The ground surface around the RWPS will be at an elevation of 138.5m asl, above the upper limit of the reservoir levels (OPUS, 2017). **Conveyance:** Land conveyance pipelines (raw water and treated water) will be underground and have a minimum 1.2m cover.	Optimal		N		Sustain current action	N/A
R2	Flooding of WTP from extreme rainfall events (pluvial flooding)	Precip	All	N/A	S	M	Heavy rainfall events are projected to increase and historically this area has flooded on approximately an annual basis (see Phase 1 Preliminary Assessment Report).	M	Flooding may cause extensive and costly infrastructure damage and pose a threat of injury or death to operation personnel and visitors to the WTP. The cost of fixing damages and the potential disruption to services during this time may involve a major financial commitment and a minor effect on the broader community.	H	H		H			L		H	M	H		**WTP:** A stormwater pond is required to attenuate a 1:100 year storm event, with an estimated drain time of less than 40 hours. Stormwater retention measures may include previous catch basins, infiltration trenches, infiltration basin, reduced lot grading. The location of the WTP site, near the Puntledge River, is situated at an elevation of between 132m and 142m which is above the historical flood elevation of the River. **RWPS:** The access elevation into the RWPS will be situated at an elevation of 139.9 m which is at the Probably Maximum Flood elevation (139.9m geodetic elevation) of Comox Lake. In addition, The electrical room and related electrical services (BC Hydro transformer and emergency generator) will be at an elevation of 142.9m, well above the Probably Maximum Flood elevation. As Comox Lake is a reservoir lake owned and operated by BC Hydro, when the water level gets too high BC Hydro systematically increases the water released from the reservoir to avoid spillage and flooding of the lake. The reservoir will begin to free-spill over the dam at approximately 135.33m asl, however BC Hydro prefers to keep it below 134.4m asl. The ground surface around the RWPS will be at an elevation of 138.5m asl, above the upper limit of the reservoir levels (OPUS, 2017). **Conveyance:** Land conveyance pipelines (raw water and treated water) will be underground and have a minimum 1.2m cover.	Optimal		L		Sustain current action	CVRD
R3	Damage to project infrastructure from storm events	Wind	All	N/A	S	H	Projection data is unavailable for this climate variable, however several elements of the project are above ground (e.g. the pumping station and WTP). Historical wind data has shown sustained winds of up to 90km/hr, as per Phase 1 Preliminary Assessment.	L	Cost of infrastructure damage from wind and storms can require major repairs and require significant funding. Wind and storms pose a significant risk of injury or death to employees and visitors. The effects on the environment, however, are minimal.	H	H		H		L			H	L	M		The WTP and RWPS will be designed as post-disaster structures (able to attain its design and structure after extreme environmental events) as per the BC Building code. Raw water pumping station: during abnormal events, such as a loss of power supply, the station will be provided with transient surge protection to mitigate the risk of excessive high pressure waves at pump station discharge. Structures will be designed for wind loads of 0.40kPa (1-in-10yr) and 0.52kPa (1-in-50yr).	Optimal		L		Watching brief	CVRD

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (If/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R4	Increased fire risk to infrastructure owing to increased air temperatures, including risk of first fire and equipment overheating	Temp	All	N/A	S	H	The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfires have historically occurred (Aqua-Tex Scientific Consulting Ltd, 2016). Climate projections from Phase 1 of this study show a continued increase in summer temperatures combined with a slight decrease in summer precipitation, which may increase conditions favorable to wildfires. The Project is also in a location surrounded by forests, which increases its exposure.	H	Fire poses a direct threat, principally, to staff and infrastructure. Wildfires increase the amounts of dissolved materials and turbidity in drinking water, in addition to increasing erosion. If fire retardant materials are used it may also increase traces of phosphate, nitrate, and nitrite in the water above acceptable standards. Electrical fires in the facilities can cause damage to infrastructure and equipment as well as pose a danger to human lives and safety. Fire repairs can be disruptive to operations and costly.	H	H		H	H	H	L		H	M	H		The Comox Valley Water Treatment Project is subject to the codes and standards of the Fire Underwriter's Survey, The National Fire Code of Canada 2012, The British Columbia Building Code, and the National Fire Protection Association. The facilities will have fire flows provided by a domestic water pumping supply system from the clear well. The RWPS and WTP will have a fire flow of a minimum of 150L/s with sprinklers. Hydrant placement on roads will comply with the MMCD Design Guidelines as well as the 2012 British Columbia Building Code, in addition to a fire alarm system with horns, lights, and smoke detectors. The building will also contain such fire protection elements such as a site fire pump, fire department connections, fire extinguishers, and water supplies from hydrants. The roofs, floors, and load bearing walls will have a fire resistance rating of no less than one hour. (OPUS, 2017). As the watershed is the site of various logging and recreational activities there are several methods in place to reduce the risks of fire including: forestry and logging companies perform routine fire patrols have response plans in place, often above minimum standards, fire cut blocks may be used to limit spread, forest companies implement forest closures based on local conditions, campfires are not permitted within Strathcona national park, public access is restricted during times of high fire risk by fire wardens and staff (public and private), forestry operations are shut down when fire risk is high, forestry companies in the area have their own fire suppression equipment on site, and the area is large enough to allow for aerial suppression (Aqua-Tex Scientific Consulting Ltd, 2016).	Adequate	L	M		Watching brief	CVRD
R5	Damage to foundations from desiccation of soils	Soil	All	N/A	S	L	The Phase 1 Preliminary Assessment showed a projected mean decrease or no change in soil moisture.	L	Damage to infrastructure, threat to health and safety of workers, financial costs of damage and increased maintenance costs.	H	M		H					H	VL	M		As part of the geotechnical design parameters the final geotechnical report must include potential geological hazards and mitigation measures.	Adequate	N	L		Sustain current action	CVRD
R6	High winds from storms leading to damage of structures	Wind	All	N/A	S	M	Historical wind data has shown sustained winds of up to 90km/hr, as per Phase 1 Preliminary Assessment. However, the highest average monthly wind speed is 14km/hr.	L	High winds can cause both direct and indirect damage to infrastructure, for example by toppling trees and sending debris flying. Such damage is a threat to human lives and safety, and may constitute a financial burden in repairs. This may impact both the primary facilities (WTP, RWPS) as well as supporting infrastructure such as exposed piping and roads.	H	H		M			L	L	M	L			The WTP and RWPS will be designed as post-disaster structures (able to attain its design and structure after extreme environmental events) as per the BC Building code. Structures will be designed for wind loads of 0.40kPa (1-in-10yr) and 0.52kPa (1-in-50yr).	Adequate	L				CVRD
R7	Changing water temperatures impacting the thermal expansion and contraction of the marine pipeline	Temp	O&M	N/A	C	L	HDPE Pipe has a high coefficient of thermal expansion and will expand and contract as a result of temperature changes. Lake water varies between 5 degrees and 11 degrees Celsius and may increase by 0.01 degrees under RCP8.5. (OPUS, 2017; Ecofish 2018).	VL	Fluctuations in lake temperature will result in expansion or contraction of the HDPE piping planned for construction. Anchored pipe may apply stresses to restraining structures which can cause significant stress and require repair.	M			M					M		L		The design and installation of the marine pipeline consider the connection between the foundation pedestal and intake assembly and will be configured to allow for flexibility of movement due to marine pipeline thermal expansion/contraction. The direction(s) and amount(s) of movement(s) will be determined during final design of the marine pipeline in order to design the corresponding flexible connection between the intake assembly and the foundation.	Adequate		N		Sustain current action	N/A
R8	Vegetation death reducing soil stability of the Project site	Precip	O&M	N/A	C	M	Increase in summer drought conditions as well as increases in evapotranspiration may cause vegetation death which may destabilize soil stability.	L	Decreased soil stability poses a danger to the infrastructure of the plant itself as well as increases erosion rates, which may impact water conditions.	M	M		H		L			M		L		As part of the geotechnical design parameters the final geotechnical report must include potential geological hazards and mitigation measures.	Adequate		N		Sustain current action	CVRD
R9	Storm events disabling communication systems	Wind	All	N/A	S	L	Storm events are projected to increase locally and have already been responsible for disabling communication on Vancouver Island and in British Columbia. (Phase 1 of this study).	M	Lack of ability to communicate with other buildings on site and with external sources can negatively impact operations and is a threat to the health and safety of employees and visitors.	L	M							M	L	M		Redundant fiber optic communication trunk, radio communication, and telephone services. Instrumentation and controls also have redundancy measures, including no single-point of failure and strategic module connections. Fiber optic communication trunk will be buried and allow for future redundancy for installation of new fibers.	Adequate	L			Sustain current action	CVRD
R10	Storm/flood conditions reducing access to project infrastructure for staff, deliveries, or emergency services	All	All	N/A	S	M	Storm events, heavy precipitation, and high winds can cause flooding and/or damage to the road accessing the WTP.	M	Reduced operational capacity and health and safety concerns	L	M		L					M	M			There are multiple redundancies in place to keep the WTP and RWSP operational in the event of a storm or emergency event including two backup generators for the WTP and RWSP, a redundancy of chlorine, and various communication systems including fiber optic, radio, and telephone. The facility will allow for external monitoring and control in the event that access is reduced. Multiple access routes and entries are available for the facilities.	Adequate	L			Watching brief	CVRD

RISK ANALYSIS TABLE – WATER QUALITY IMPACTS

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R11	Extreme rainfall events causing increased mobilization of sediments and pollutants	Precip	O&M	Sediment and pollutant thresholds in drinking water are set by the Government of British Columbia.	S	M	Both drought and heavy precipitation events increase erosion and overland flow of sediments and pollutants, both of which are projected to occur in the study area. In addition, rainfall may increase stream erosion. These conditions have also been experienced historically (Phase 1 Assessment Report)	H	Large rainfall events increase water turbidity and are associated with increased pathogens. This may reduce disinfection capacity of chlorine which poses a risk to human health. In addition, adjusting the water treatment process may constitute an increase in operational cost and impact local public opinion of the project. Environmentally this may pose minimal effect to the natural environment contained within the boundary area.		H		L		L		L	L		M		The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment (OPUS. 2017).	Optimal		N		Sustain current action	CVRD
R12	Increased risk of blue-algal blooms (cyanobacteria) in Comox Lake owing to increased temperatures	Temp	O&M	MAC 0.0015 mg/L (maximum acceptable amount) (Government of Canada, 2017) .	S	L	Algal blooms increase in warmer temperatures, which are projected. Higher atmospheric CO2 levels, and increased erosion can introduce more nutrients in the lake which increase the algal growth. In addition potential reduced above-ground flow causes an increase in nutrient concentration into lakes.	M	Cyanobacteria (blue green algae) and other forms of algal growth release toxins when they decay and die which can be harmful to human health. This may cause rashes, nausea, vomiting, stomach pains, fever and headaches in humans as well as liver and brain damage. This is a possible carcinogen. Treating this water may constitute an additional cost. Some damage may occur to local environmental systems, notably he aquatic ecosystem.		M		L		M			M		M		The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment (OPUS. 2017).	Optimal		N		Sustain current action	CVRD
R13	Increase in water turbidity from increase in phytoplankton	Temp	O&M	<1 NTU (nephelometric turbidity unit)	C	L	The science isn't conclusive but the general consensus is that warmer surface water temperatures will decrease plankton populations.	VL	May reduce disinfection capacity of chlorine which poses a threat to human health and may require increased operational cost. May have minor impacts on the local environment.		L		L		L			L		N		The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment (OPUS. 2017). It will reduce the presence of water turbidity from phytoplankton to an acceptable amount.	Adequate		N		Sustain current action	CVRD
R14	Increased water surface turbulence due to high winds	Wind	O&M	< 1NTU (CVRD, 2018)	S	M	Increased turbidity from wind primarily impacts shallow lakes (Comox Lake has an average depth of 61m and a lowest depth of 109m, and does not fall into this category) (OPUS, 2017).	L	Increased surface turbulence may increase turbidity which may interfere with chlorination, may increase the risk of bacteria (CVRD, 2018) and may result in increased operational costs of water treatment.		M		L				L	L		L		The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment (OPUS. 2017).	Adequate		N		Sustain current action	CVRD
R15	Increased overland runoff from large precipitation events	Precip	O&M	<1 NTU (CVRD, 2018)	S	H	Projected increased winter and fall precipitation (Phase 1 of this study) as well as projected increased winter and fall river flow rates (Ecofish, 2018) may increase erosion rates and increase rates of transport of particles due to overland flow. In addition, projected dryer summer conditions coupled with projected increases in large storm events may dislodge more sediments than under normal conditions.	H	Increase in overland pollutants introduced into the water system, some of which may be harmful to human health and/or cause an increase in the cost of water treatment. in addition, increased turbidity interferes with chlorination, may increase the risk of bacteria (CVRD, 2018) and may cause some reputational harm as it is aesthetically unpleasing and dangerous.		M		L				L	L		M		The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment (OPUS. 2017).	Adequate		N		Sustain current action	BC Hydro, FLNRO and CVRD
R16	Increased risk of waterborne pathogens being driven into the water system due to increased precipitation intensities	Precip	O&M	Thresholds are provided by the Government of (British Columbia Ministry of the Environment, 2017).	C	L	While heavy precipitation events are expected to increase, the project is isolated from common contamination sources (agriculture and sewage systems). Comox Valley has already had boiled water advisories but the purpose of this plant is to address this (Phase 1 Preliminary Assessment Report, CVRD, 2018).	L	Contaminated drinking water may lead to human illness or death in extreme cases and slightly impact the local environment.		H				L			H		M		The project itself will increase water treatment including filtration, ultraviolet treatment, and chlorination to raise water standards to BC regulations. While this is not an adaptation to climate change, it should address subpar water quality conditions. (CVRD, 2018).	Adequate		L		Sustain current action	CVRD

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R17	Reduction of input water quality owing to fires from increased erosion rates, use of fire retardants, changes in hydrological cycles, and nutrient loading from destruction of surrounding habitat and wildlife.	Temp	All	N/A	S	H	The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfires have historically occurred (Aqua-Tex Scientific Consulting Ltd. 2016). Climate projections (see Phase 1 of this study) project a continued increase in summer temperatures combined with a slight decrease in summer precipitation; this may increase dry conditions favoured by wildfires. In addition, the Project is located in close proximity to forests which increases its exposure to forest fires. Furthermore, being in a fire prone area puts the project at risk from ash contamination, changes in erosion rates due to destruction of stabilizing vegetation, decaying wildlife contaminating the water, and contamination from any retardant used by the region to combat wildfires. This combination of proximity to forests, historical instances of fires in the area, and projected climate conditions which increase the conditions favourable to fires give this risk a 'High' Likelihood Rating.	H	Fires can cause increased erosion and sediment rates, changes to hydrological structures due to vegetation destruction changing the magnitude and frequency of flooding events and overland flow transporting sediments, introduction of ash and fire retardant into the water system, and introduction of excess nutrients from fire retardant and animals deaths. This may lead to an increase in bacterial loading, water turbidity, changes in nutrient content and changes in the amount of water input into the lake. This may put an excess strain on treatment infrastructure, pose an increased risk to human health through contaminated water, increase the cost of filtration, destroy local habitats, reduce local tourism and fishing capabilities, require a change in government policy, reduce logging stock, and cause social and reputational harm through the destruction of landscapes and reduction in the availability to provide clean water.	M	H	L	M	L	VH	H	L	H				The project itself will increase water treatment standards and operations including options for pre-treatment, flocculation, direct filtration, membrane filtration, primary disinfection, chlorination, residual treatment, and clean-in place treatment. The main loop and secondary roads will be able to accommodate fire trucks (OPUS. 2017). The Comox Valley Water Treatment Project is subject to the codes and standards of the Fire Underwriter's Survey, The National Fire Code of Canada 2012, The British Columbia Building Code, and the National Fire Protection Association. The facilities will have fire flows provided by a domestic water pumping supply system from the clear well. The RWPS and WTP will have a fire flow of a minimum of 150L/s with sprinklers. Hydrant placement on roads will comply with the MMCD Design Guidelines as well as the 2012 British Columbia Building Code, in addition to a fire alarm system with horns, lights, and smoke detectors (OPUS, 2017). As the watershed is the site of various logging and recreational activities there are several methods in place to reduce the risks of fire including: forestry and logging companies perform routine fire patrols have response plans in place, often above minimum standards, fire cut blocks may be used to limit spread, forest companies implement forest closures based on local conditions, campfires are not permitted within Strathcona national park, public access is restricted during times of high fire risk by fire wardens and staff (public and private), forestry operations are shut down when fire risk is high, forestry companies in the area have their own fire suppression equipment on site, and the area is large enough to allow for aerial suppression (Aqua-Tex Scientific Consulting Ltd, 2016). In addition, the Comox Valley Lake Watershed protection plan has recommended the following actions: introducing fire suppression into the emergency management plan, better integration of fire management through the various parties in the watershed (private vs public entities), and reducing the unnecessary use of fire retardants (Aqua-Tex Scientific Consulting Ltd, 2016).	Adequate		L	L	Sustain current action	BC Hydro, FLNRO and CVRD
R18	Decreased summer precipitation with increased evapotranspiration rates may reduce the capacity of surface water to dilute and remove pollutants and may change patterns of microbial growth and increase levels of biological contamination.	Precip	O&M	Thresholds provided by the Government of British Columbia.	C	L	Evapotranspiration and temperature are projected to increase for Summer and Spring (Phase 1 of this study).	M	Decrease in incoming water quality may require more treatment, a higher operating cost, and/or pose a risk to human health and the local environment.		M		L		L			L		L		The project itself will increase water treatment including filtration, ultraviolet treatment, and chlorination to raise water standards to BC regulations. While this is not an adaptation to climate change, it should address subpar water quality conditions. (CVRD, 2018). In addition, the design and configuration of the WTP process will allow for the addition of a high rate clarification process to the Primary Treatment System immediately downstream of the flocculation process to control algae and other raw water constituents that could negatively impact the direct filtration process performance. The flocculation basin and filter basin configuration and associated channels will be such that the future clarification basin can be easily and efficiently integrated into the Primary Treatment Process.	Adequate		N		Sustain current action	CVRD

RISK ANALYSIS TABLE – WATER AVAILABILITY IMPACTS

ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood: Likelihood rationale	Likelihood: Likelihood Rating	Consequence: Consequence rationale	Consequence: Infrastructure	Consequence: H&S	Consequence: Governance	Consequence: Financial	Consequence: Social	Consequence: Environment	Consequence: Economy	Consequence: Reputation	Consequence: Combined Rating	Initial risk rating: Construction	Initial risk rating: 2050s	Initial risk rating: 2080s	Control measures: Summary	Control measures: Adequacy	Residual risk rating: Construction	Residual risk rating: 2050s	Residual risk rating: 2080s	Adaptation response	Responsible
R19	Increased temperatures leading to glacial retreat and risk of reduced inflow to Comox Lake	Temp	O&M	105.0m Elevation	C	H	It has been estimated that the glacial system will disappear within 25 years. Climate projections show increased summer temperatures and decreased snowfall in the winter (McCulloch, 2014) - see Phase 1 Preliminary Assessment Report. However, the glacier only contributes a maximum of 3% of flow to Comox Lake during the summer months and is not considered a significant source of water (PCIP, 2018).	L	With a maximum of 3% of the inflow coming from glaciers (and numbers more likely ranging from 0.1%-0.3% annually), reducing glacial inflow would result in an insignificant change in the inflow of the Lake (PCIP, 2018). A small reduction in water has little risk to human health and water supply in the area, requires no changes to government or management, has a negligible cost, and has very little to no impact on the economy. The decline of the glaciers does significantly alter a natural environment may impact species.		VL	L	L		H	L		L		L		As per BC Hydro's Puntledge River Project Water Use Plan, BC Hydro will manage operations to maintain a 95 percent confidence level of providing a minimum flow of 15.6 m3/s in the river below the powerhouse at all times. (This is as measured in Gauge 8 (WSC Station 08HB006) located on Puntledge River after the BCH Powerhouse.) In addition, BC Hydro maintains the maximum lake level, maximum flow level of the Puntledge River, rate of flow change, and provides consideration to the downriver habitats of fish including spawning and migration areas.	Adequate		L		Sustain current action	BC Hydro, FLNRO and CVRD
R20	Changes in stability of annual water availability due to retreating glaciers	Temp	O&M	N/A	C	H	Glaciers are expected to completely disappear in the area in 25 years (McCulloch, 2014). Glacial waters provide a buffer in water availability at the end of spring as they melt and stabilize water availability, which may be compromised. However, they compose an insignificant source of inflow to Comox Lake, with a maximum 3% contribution during the summer months (PCIP, 2018).	H	Reduced freshwater availability, changes in local hydrological cycle. PCIP (2018) suggests that Glaciers have a minimal impact on inflow rate to Comox Lake (less than 3%, closer to 0.1-0.3% of total annual inflow). Low health and safety consequence from water shortages which may require slight changes to governance and an increase in operational costs. Glaciers melting disrupts an environment and the species which reside in it.	L	L	M	L		M	L		L		M		As per BC Hydro's Puntledge River Project Water Use Plan, BC Hydro will manage operations to maintain a 95 percent confidence level of providing a minimum flow of 15.6 m3/s in the river below the powerhouse at all times. (This is as measured in Gauge 8 (WSC Station 08HB006) located on Puntledge River after the BCH Powerhouse.) In addition, BC Hydro maintains the maximum lake level, maximum flow level of the Puntledge River, rate of flow change, and provides consideration to the downriver habitats of fish including spawning and migration areas.	Adequate		L		Watching brief	BC Hydro, FLNRO and CVRD
R21	Low flows of intake water owing to reduced summer rainfall	Precip	O&M	N/A	S	H	Summer precipitation is projected to decrease (Phase 1) which may reduce fluvial and pluvial water sources. There have been historically low lake levels due to drought conditions.	H	Inability to provide water for domestic, CVRD, BCH, fire prevention, conservation, irrigation, or transport management purposes. Small risk of safety to public due to water shortage concerns. Risk to Salmon spawning habitats which slightly impacts the environment and economy. The infrastructure requires water to operate and a reduction may slightly impact operational costs.	L	L		M		M	VL		M		[redacted]		As per BC Hydro's Puntledge River Project Water Use Plan, BC Hydro will manage operations to maintain a 95 percent confidence level of providing a minimum flow of 15.6 m3/s in the river below the powerhouse at all times. (This is as measured in Gauge 8 (WSC Station 08HB006) located on Puntledge River after the BCH Powerhouse.) In addition, BC Hydro maintains the maximum lake level, maximum flow level of the Puntledge River, rate of flow change, and provides consideration to the downriver habitats of fish including spawning and migration areas.	Adequate		L		Sustain current action	BC Hydro, FLNRO and CVRD
R22	Low flows owing to increases in evapotranspiratio n rates	Evapo-transp	O&M	N/A	C	M	Evapotranspiration is projected to increase for the Spring and Summer which may reduce availability of water and flow (Phase 1 of this study). However, the EcoFish study notes that the reservoir is assumed to have negligible levels of evaporation.	VL	Inability to provide water for domestic, CVRD, BCH, fire prevention, conservation, irrigation, or transport management purposes. Risk of safety to workers. Risk to Salmon spawning habitats.	L	L		M		L	VL		L		N		As per BC Hydro's Puntledge River Project Water Use Plan BC Hydro will manage operations to maintain a 95 percent confidence level of providing a minimum flow of 15.6 m3/s in the river below the powerhouse at all times (This is as measured in Gauge 8 (WSC Station 08HB006) located on Puntledge River after the BCH Powerhouse). In addition, BC Hydro maintains the maximum lake level, maximum flow level of the Puntledge River, rate of flow change, and provides consideration to the downriver habitats of fish including spawning and migration areas.	Adequate		N		Sustain current action	BC Hydro, FLNRO and CVRD

RISK ANALYSIS TABLE – DISRUPTION TO OPERATIONS AND SERVICE DELIVERY

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R23	Risk to ability to sustain operation during major wildfire events owing to increased water demand	Temp	O&M	N/A	S	H	The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfire have historically occurred (Aqua-Tex Scientific Consulting Ltd, 2016). Climate projections from Phase 1 of this study show a continued increased in summer temperatures combined with a slight decrease in summer precipitation, which may increase conditions favorable to wildfires. The Project is also in a location surrounded by forests, which increases the exposure.	M	Comox Lake is one of four reservoirs maintained by CVRD and provides water storage for fire fighting, emergencies (i.e. watermain breaks), equalization, and drinking water supply. In the event of a large forest fire water may need to be diverted from any of the above activities for fire fighting, which may impact the availability of water for drinking water, equalization, and other emergencies. This may impact the availability of clean potable water for consumption, incur an extra financial cost, and damage the downstream environment dependent on maintained water flows.		M		L		H			H		[illegible]		CVRD will be adding two 10 million liter storage tanks to the reservoir capacity in the region which will make up for a shortfall in the event of a fire. In addition, CVRD can implement four stages of water restrictions, the most severe of which limits water use to drinking, food preparation, and personal hygiene. This will reduce water demand during the event of a wildfire event.	Adequate		L	L	More action needed	CVRD
R24	Risk to operations in the event of a fire from forced staff evacuations	Temp	O&M	N/A	S	H	The Comox Lake watershed is partially located in a summer-dry maritime subzone where precipitation decreases in the summer and where large wildfire have historically occurred (Aqua-Tex Scientific Consulting Ltd, 2016). Climate projections from Phase 1 of this study show a continued increased in summer temperatures combined with a slight decrease in summer precipitation, which may increase conditions favorable to wildfires. The Project is also in a location surrounded by forests, which increases the exposure.	H	In the event of a fire staff may need to evacuate the premises for an undetermined period of time. This may cause interruptions in service, decrease in water quality, or a complete shutdown of operations. This may impact the water quality of the region affecting the health and safety of the population, incur additional costs, and impact the reputation of the Project.	L	M		H			L	L	M		M	M	The Project has been designed to operate independently via remote operation for several weeks if necessary.	Adequate		L	L	Sustain current action	CVRD
R25	Increased demand for water due to increasing temperatures and decreasing summer precipitation	Temp	O&M	N/A	C	L	Summer drought temperatures are projected to increase which may increase the demand for water from residents, industry, and commercial sources (see Phase 1). Under RCP8.5 municipal water demand is projected to increase from a withdrawal rate of 0.42 m3/s (current) to 0.85m3/s in 50 years under RCP8.5 (assuming a future license capacity of 15.5 M m3/y and water provisions to the K'omoks First Nations) (EcoFish, 2018).	M	Inability to provide water for domestic, CVRD, BCH, fire prevention, conservation, irrigation, or transport management purposes as well as human drinking water. May increase operational and financial costs, as well as have localized social impacts. Increasing demands for water may lead to significant impacts on the local environment due to drawing from a different water source.		L	M	L	L	M			M		M		The project involves the potential to increase the capacity of treated water from 75 ML/Day to 120 ML/Day, which is expected to mitigate the risks of increased demand (OPUS, 2017; EcoFish, 2018).	Adequate		N		Sustain current action	CVRD
R26	Storms leading to power outages	Wind	All	N/A	S	M	Storm events are projected to increase and have historically already led to mass power outages (see Phase 1).	H	Inability to provide water for domestic, CVRD, BCH, fire prevention, conservation, irrigation, or transport management purposes. Risk of safety to workers, and potentially significant financial costs to repair.	H	H		M			L	L	M	M	[illegible]		The electrical power system will be designed with high reliability. Each facility will be equipped with redundant diesel fuel power generators as a backup power supply. These generators will be housed in a custom, walk-in, weatherproof, vandal-proof enclosure and supply 24 hours of backup power. Two 750 kW standby generators will be required to provide full backup to the WTP facility. Two 500kW standby generators would be required to provide full backup to the RWPS.	Adequate	N	L		Sustain current action	BC Hydro

RISK ANALYSIS TABLE – MISCELLANEOUS

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
R27	Changes in parameters such as water flow, temperature, air temperature and others reducing fish populations	Precip	O&M	N/A	C	M	Ecofish (2018) predicts a 4-5% decrease in Chinook salmon spawning habitat under RCP8.5 in the next 50 years. This is not expected to be a significant decrease.	M	Potential reduced tourism, fishing capacity. disruption to fish habitats, disruption to the natural ecosystem. May require increased governance and effect the local community and economy as well as the reputation of the plant.			L	L	M	H	L	L	M		M		The Fisheries Act requires that projects avoid causing harm to fish unless authorized by the DFO. This applies to work being conducted in or near waterbodies that support fish that are part of or that support a commercial, recreational or aboriginal fishery. As per BC Hydro's Puntledge River Project Water Use Plan, BC Hydro will manage operations to maintain a 95 percent confidence level of providing a minimum flow of 15.6 m3/s in the river below the powerhouse at all times. (This is as measured in Gauge 8 (WSC Station 08HB006) located on Puntledge River after the BCH Powerhouse.) In addition, BC Hydro maintains the maximum lake level, maximum flow level of the Puntledge River, rate of flow change, and provides consideration to the downriver habitats of fish including spawning and migration areas.	Adequate		L		Sustain current action	BC Hydro, FLNRO
R28	Extreme building temperature conditions (indoor)	Temp	O&M	N/A	S	M	Temperatures are projected to increase past historical norms. Daily maximum temperatures are projected to exceed 37 degrees Celsius under RCP8.5 by 2080 (Environment Canada's heat warning starts at 29 degrees Celsius, for comparison). (Phase 1 of this study).	H	Extreme heat to employees or visitors can cause dehydration, heat stroke, heat exhaustion, or death. Minor infrastructure damage due to heat require repair.	VL	H		L	L				M		M	H	There will be two separate HVAC systems (occupied areas and process/equipment areas) with outdoor design temperature ranges of -16 to 36 degrees Celsius, indoor design temperatures for normally occupied spaces of 20 - 22 degrees Celsius (summer and winter respectively), indoor design temperature for process spaces of 10 degrees Celsius, and an acceptable level of redundancy. The existing design is accommodative of a larger HVAC system i nthe future. Future upgrades can be made in the event of extended and sustained design temperature changes. Upgrades would coincide with the natural replacement cycle of the existing HVAC system.	Adequate		L	L	Watching brief	CVRD

OPPORTUNITY ANALYSIS TABLE

							Likelihood		Consequence										Initial risk rating			Control measures		Residual risk rating				
ID	Risk/Opportunity	Climate variable	Project phase	Threshold (if/where applicable)	Type of event	Confidence	Likelihood rationale	Likelihood Rating	Consequence rationale	Infrastructure	H&S	Governance	Financial	Social	Environment	Economy	Reputation	Combined Rating	Construction	2050s	2080s	Summary	Adequacy	Construction	2050s	2080s	Adaptation response	Responsible
O1	Extra heat available through warmer temperatures may introduce an opportunity to improve some aspects of treatment (i.e. cuagulation and settlement processes) and lead to increased removal efficiencies and reduced treatment costs	Temp	O&M	N/A	S	L	As per Phase 1 assessment average winter temperatures are expected to increase under both RCP4.5 and RCP8.5 for the mid and end century projections.	M	Reduced treatment/operational cost. Water quality (raw and treated) will be measured and trended in real time with ability to modify dosages of chemicals and optimize the treatment processes to maintain water quality targets.	L			L					L		L		N/A	N/A		L		Watching brief	CVRD
O2	Increased winter temperatures may increase the opportunity to reduce complications due to freezing such as service disruptions from frozen infrastructure (i.e pipes)	Temp	O&M	N/A	S	M	As per Phase 1 assessment average winter temperatures are expected to increase under both RCP4.5 and RCP8.5 for the mid and end century projections.	M	Possible reductions in damage and operational delays as well as costs from effects of cold weather such as frozen infrastructure.	L			L					L		L		N/A	N/A		L		Watching brief	CVRD

Pages 124-161
are withheld
pursuant to paragraph
13(1)(c)
of the *Access to Information Act*

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Les pages 124-161
Font l'objet d'une exception totale
conformément à la disposition du paragraphe
13(1)(c)
de la *loi sur l'accès à l'information*